

APPENDIX A:

IAQ Survey Results from the Healthy, Efficient, New Gas Homes Study

Abstract

As a part of the Healthy Efficient New Gas Homes (HENGH) project, an occupant survey was conducted to obtain information about mechanical ventilation characteristics and occupant satisfaction of new homes. This survey was conducted by Lawrence Berkeley National Laboratory (LBNL) using the web-based LimeSurvey tool. The online survey contains 56 questions and takes approximately 20 minutes to complete. A total of 3,853 participants started the survey, of which 2,781 participants (72%) completed Part I of the survey, and 2,648 (69%) completed both parts of the survey. Basic statistics of the survey responses were summarized using all valid responses. In addition to summarizing survey data, statistical analyses were performed to characterize potential associations between IAQ satisfaction, comfort, and health indicators (i.e., any person in household with diagnosed allergy and/or asthma) with household parameters, such as floor area, number of occupants, kitchen and bathroom ventilation, window opening, and use of air cleaners. Logistic and ordinal logistic regression was used to characterize the relationship between a set of explanatory variables and the response parameter. Most surveyed homes are single-family detached homes, built between 2002 and 2006. Survey respondents were generally more satisfied with the indoor air quality in their home than the outdoor air quality near where they live. But because survey respondents tend to associate indoor air quality with other indoor environmental conditions, such as thermal comfort, air movement, and dryness, the term “indoor air quality” potentially has many meanings that could complicate interpretation of the survey data.

1 Background

The goals of the Healthy Efficient New Gas Homes (HENGH) project were to measure indoor air quality (IAQ) and document mechanical ventilation system characteristic in homes that were built to meet California’s 2008 Title 24 Building Code (CEC, 2008). As a complement to the field study, a web-based survey was conducted to obtain information about mechanical ventilation characteristics and occupant satisfaction in homes built to the 2008 standards and also to homes built to directly preceding versions of the standards. Data were collected on the following parameters:

- Location and date of construction.
- House and household characteristics.
- Types of mechanical ventilation equipment and gas appliances installed, and how they are used.
- Occupant satisfaction with IAQ and other indoor environmental parameters.

- Occupant activities related to IAQ, such as window opening and use of an air cleaner.

Survey respondents were also asked if they would be interested in participating in the field study, in which indoor air quality and mechanical ventilation performance data were collected. This document describes the results of the occupant survey.

2 Method

2.1 Survey Description

This survey was conducted by Lawrence Berkeley National Laboratory (LBNL) using LimeSurvey, an open source online survey application. All survey data submitted by respondents is stored securely on a LBNL data server. The online survey contained 56 questions and was designed to enable most respondents to complete it in approximately 20 minutes. Invitations to participate in the self-administrated survey were sent to Southern California Gas Company (SoCalGas) customers by e-mail (see Appendix A-1). SoCalGas reached out to approximately 120,000 customers by email between June and September 2015. In addition, LBNL also advertised the survey through other professional contacts in the field of indoor air quality and energy efficiency.

The complete list of survey questions are given in Appendix A-2). The survey was reviewed and approved by LBNL's Institutional Review Board for Human Subjects Research. There were three mandatory eligibility questions: house type, year built, and zip code. Also, before start the survey, participants had to self-certify that they were 18 or order. Survey respondents had to live in a single-family detached house, townhouse, or duplex built in 2002 or later, with a California zip code. All subsequent questions were optional, meaning that survey respondents could skip any questions that they did not want to answer or for which they did not know the answer.

Table 1 summarizes the types of questions asked in the survey. The survey had two parts. The first part was a short survey on household indoor air quality (IAQ) satisfaction and characteristics. The second part asked follow-up questions with more details and it designed to take about 15 minutes to complete. A \$100 sweepstake was available to all respondents regardless if they completed the survey or not, provided that they submit their contact information for notification purposes.

Table 1 Summary of survey questions.

Survey Part I	
Eligibility Questions	House type
	Year built
	Zip code
Home and Household Characteristics	Size of home
	Number of occupants
	Presence of natural gas appliance
	Mechanical ventilation equipment
Air Quality Satisfaction	Indoor air quality
	Outdoor air quality
Comfort Level	Too hot / too cold in some rooms
	Air movement
	Air dryness
	Musty odor
Survey Part II	
Detailed Home Characteristics	Number of stories
	Foundation type
	Number of bedrooms
	Number of bathrooms
	Garage type
	Year moved in
	Ownership
Natural Gas Appliances	Gas appliance locations
	Forced air system particle filtration

Kitchen Range Hood / Exhaust Fan	Kitchen ventilation type and usage
Bathroom Exhaust Fan	Bathroom exhaust fan control
Mechanical Ventilation System	Particle filtration type (outside air) User knowledge and satisfaction
Window Opening	Usage by season
Occupancy and Indoor Activities	Occupied hours Cooking activities Other activities: smoking, burning candles, vacuuming, cleaning agent use, spray use, pesticide spray use, solvent use, humidifier use, dehumidifier use
Other Indoor Sources	Air freshener use Wearing shoes Pets
Use of Air Cleaners and Health Indicators	Air cleaner use and location Asthma Allergy
Demographic Information	Age Education Race Income

The online survey contained several features to help respondents answer questions to the best of their knowledge. Example photos of mechanical ventilation systems and air filters were included in the survey (see Appendix A-2) to help respondents identify the type of equipment that they have in their home. Because it is difficult to identify particle filters by the physical appearance alone, common efficiency ratings used by leading filter manufacturers and retailers – e.g., 3M’s MPR (microparticle performance rating), Home Depot’s FPR (filter performance rating) – were also described in the survey to help respondents report the efficiency of their filter. The online version of the survey used logical and “piping” features to allow respondents skip or customized a future question based on answer to a previous question.

2.2 Survey Responses

A total of 3,853 participants started the survey, of which 2,781 participants (72%) completed Part I of the survey, and 2,648 (69%) completed both parts of the survey. Most survey respondents provided their contact information and participated in the \$100 sweepstake draw.

Table 2 shows the cities where survey respondents resided based on the zip codes they provided. The majority of them are from the Southern California area. Riverside and Palm Springs had the highest number of participants. Relatively few respondents resided in the Central Valley and coastal parts of Northern California. At the design phase of the survey, it was the intention that the survey would also be advertised to customers in Pacific Gas & Electric service territories, which would have increased the number of respondents in Northern California and some part of the Central Valley. However, due to some difficulties in getting the necessary permission to recruit utility customers, only agreement with SoCalGas was obtained within a time frame that met the survey timeline.

Table 2 Geographical locations of survey participants (N=2,771).

City	Count (N)	City	N	City	N
Los Angeles	35	Industry	50	Bakersfield	155
Inglewood	60	San Diego	4	Mojave	212
Santa Monica	6	Palm Springs	621	Fresno	1
Torrance	9	San Bernardino	15	Palo Alto	1
Long Beach	21	Riverside	842	Oakland	7
Pasadena	21	Santa Ana	14	San Jose	4
Van Nuys	183	Anaheim	194	Stockton	3
Burbank	7	Oxnard	112	Sacramento	1
North Hollywood	4	Santa Barbara	188	Maryville	1

2.3 Survey Analysis

Univariate statistics of the survey responses were summarized using all valid responses. A few of the responses to open-ended questions were checked for validity, including year built, floor area, and number of occupants. Invalid answers (e.g., year built <1000, number of occupants >100) were discarded. In total, only a small number of responses (about 10) were discarded from this validation check.

In addition to summarizing survey data, statistical analyses were performed to characterize potential associations between IAQ satisfaction, comfort, and health indicators (i.e., any person in household with diagnosed allergy and/or asthma) with household parameters, such as floor area, number of occupants, kitchen and bathroom ventilation, window opening, and use of air

cleaners. Logistic and ordinal logistic regression was used to evaluate relationships between potential explanatory variables and a response parameter.

Ordinal logistic regression was used to analyze data because the response variables are in ordered categories, such as those measuring opinion (e.g., very dissatisfied, somewhat dissatisfied, neutral, somewhat satisfied, very satisfied) and frequency (e.g., never, rarely, sometimes, most of the time, always). Also, these values are not continuous. Ordinal logistic regression is able to determine which of the independent variables have a statistically significant effect on the dependent variable. This regression method was used in similar survey studies that investigated the relationships between occupant IAQ satisfaction and IAQ parameters (Frontczak et al. 2012, Zalejska-Jonsson and Wilhelmsson 2013).

In performing the regression analysis, the correlations between survey responses to the different questions were tested to determine whether potential explanatory variables are independent of each other. After that, logistic regression is used for categorical parameters, and ordinal logistic regression for survey responses that have multiple ordered categories to characterize the relationship between explanatory variables and the response parameter.

The statistical software R was used for the statistical analysis. For ordinal logistic regression analysis, this study used the **polr** command from the **MASS** package to estimate an ordered logistic regression model. In performing the regression, survey responses with any missing data were excluded from the set of explanatory variables and the response parameter being analyzed. Results of regression analysis are reported in the form of odds ratios to describe the effect of explanatory variables on the response parameter.

For example, an ordinal logistic regression is performed to characterize the relationship between occupant indoor air quality satisfaction and explanatory variables. Equation (1) is the ordinal logistic regression model.

$$\log \left(\frac{P(Y \leq k)}{P(Y > k)} \right) = a_k + b_1 x_1 + b_2 x_2 + b_3 x_3 + \dots \quad (1)$$

where P is the probability of indoor air quality satisfaction (Y) greater or less than a certain rating (k), $b_1 \dots b_n$ are regression coefficients, and $x_1, x_2 \dots x_n$ are explanatory variables. Odds ratios (OR) are used to describe the impact of explanatory variables on the response variable, which quantify the odds of increasing IAQ satisfaction by one rating unit (e.g., from 0 to 1, from 1 to 2, etc.) as a result of one unit increase in each of the explanatory variable.

$$\text{Odds Ratios}(OR) = \frac{P(Y \geq k | x_1=1)/P(Y < k | x_1=1)}{P(Y \geq k | x_1=0)/P(Y < k | x_1=0)} = \frac{\exp[a_k + b_1(1)]}{\exp[a_k + b_1(0)]} = e^{b_1} \quad (2)$$

When the OR is greater than 1, the impact of the explanatory variable(s) on the response variable is positive. When the OR is less than 1, the impact is negative.

3 Results and Discussion

3.1 Summary of House and Household Characteristics

Table 3 summarizes the characteristics of survey participants. Most respondents (97%) lived in single-family detached homes and most (91%) were homeowners. Most homes (63%) were between 140 and 279 m² (1,500–3,000 ft²). There were similar numbers of single (49%) and two-story (48%) homes. Homes tended to have either 3 (30%) or 4 (37%) bedrooms. Most homes (72%) had 3 or more bathrooms. Almost half of the homes (46%) were occupied by two or fewer occupants.

Most homes (76%) were built between 2002 and 2006, before the 2007 housing market crash. There were very few responses about homes (N=28) built after 2011, which is the earliest year that the homes were very likely to have been built to the 2008 Title 24 code. Most homes built during the years of 2008-2010 were permitted prior to the 2008 Code taking effect. Still, almost three-quarters of the homes in the survey dataset were built post 2003, which was the build year of homes that were surveyed by a prior study (CEC, 2007) on occupant satisfaction with mechanical ventilation, indoor air quality, and comfort.

Survey respondents were asked to indicate all races/ethnicities of people living in their household. This means that there may have been more than one answer for each survey completed. White, Caucasian is the most common (53%), followed by Hispanic/Latino (17%) and Asian or Pacific Islander (14%). The majority (60%) of heads of household of the surveyed homes had a college or more advanced degree. Almost half of the households (46%) had a combined income of above \$100,000.

Table 4 shows the characteristics of gas appliances and mechanical ventilation systems. Survey respondents were asked to select all gas appliances they had in their homes. Since the survey participants were SoCalGas customers, most of homes had natural gas appliances. Most homes had a central gas furnace (88%), gas water heater (89%), and used gas for cooking (92% had gas cooktop). In addition, 85% indicated that they had a gas clothes dryer, and 72% had a gas fireplace. Gas furnaces were most commonly installed in the attic (73%) and water heater were most commonly installed in the garage (87%). Six percent of respondents did not know where their furnace was located and 12% did not know where their water heater was located.

Most survey respondents indicated that they had a kitchen range hood (91%) and bathroom exhaust fans (91%) in their home. Whole-house fans (18%) were relatively common based on the survey responses. A small percentage of survey respondents (8%) indicated that they had a kitchen exhaust fan separate from the range hood. Few of the respondents (4%) reported having a continuously operating exhaust fan for ventilation.

Most survey respondents (76%) indicated that they were aware that they had a particle air filter in their central forced air system; 4% thought their system did not have a filter and 20% did not know or answered “NA”. 2516 respondents answered that they have a particle filter in their center air forced system. About one-third (34%) of the respondents describe their air filter as “traditional, inexpensive” type. A larger fraction of homes (53%) indicated that they have either medium (MERV 8-11) or high (MERV ≥12) efficiency air filters.

Table 3 Summary of basic house and household characteristics in surveyed homes.

Parameter	Survey Response Counts (%)							
Floor Area m2 (ft2)	<140	140–186	186–232	232–279	279–325	325–372	>372	NA
	(<1500)	(1500–2000)	(2000–2500)	(2500–3000)	(3000–3500)	(3500–4000)	(>4000)	
	198	584	692	568	354	196	145	34
	(7%)	(21%)	(25%)	(20.5%)	(13%)	(7%)	(5%)	(1%)
Stories	1	2	3	Other				
	1364	1318	52	37				
	(49%)	(48%)	(2%)	(1%)				
Year built	2002	2003–2004	2005–2006	2007–2008	2009–2010	>2011		
	346	799	982	473	143	28		
	(12%)	(29%)	(35%)	(17%)	(5%)	(1%)		
Ownership	Own	Rent	Other	NA				
	2510	223	9	29				
	(91%)	(8%)	(0.3%)	(1%)				
House Types	Single Family	Town House	Duplex	Other				
	2687	69	15	0				
	(97%)	(2.5%)	(0.5%)					

Parameter		Survey Response Counts (%)							
Foundation Types	Concrete Slab	Crawlspace	Basement	Don't Know	NA				
	2604 (94%)	63 (2%)	24 (1%)	73 (2.6%)	7 (0.3%)				
Number of occupants	≤2	3	4	5	≥6	NA			
	1228 (46%)	423 (15%)	513 (19%)	291 (11%)	237 (9%)	19 (1%)			
Number of Bedrooms	≤2	3	4	5	≥6	NA			
	269 (10%)	845 (30%)	1026 (37%)	506 (18%)	84 (3%)	38 (1%)			
Number of bathrooms	≤2	3	4	5	≥6	NA			
	749 (27%)	1412 (51%)	388 (14%)	155 (6%)	33 (1%)	34 (1%)			
Education Level	No Schooling	1 to 8 th Grade	9 th to 12 th Grade	Completed High School	Some College	Associate's Degree	College Degree	Graduate Degree	NA
	4 (0.1%)	2 (0.1%)	22 (1%)	140 (5%)	551 (18%)	295 (11%)	845 (30%)	819 (30%)	133 (5%)

Parameter		Survey Response Counts (%)						
Races	American Indian, Alaska Native	Asian or Pacific Islander	Black, African American	Hispanic/Latino	White, Caucasian	Mixed Race	Other	NA
	62	383	152	469	1469	31	0	205
	(2%)	(14%)	(5%)	(17%)	(53%)	(1%)		(7%)
Income	Less than \$35,000	\$35,000 to \$49,999	\$50,000 to \$74,999	\$75,000 to \$99,999	\$100,000 to \$150,000	Greater than \$150,000	NA	
	134	210	399	443	697	595	293	
	(5%)	(8%)	(14%)	(16%)	(25%)	(21%)	(11%)	

Table 4 Summary of gas appliances and mechanical ventilation systems in surveyed homes.

Parameter		Survey Response Counts (%)								
Gas Appliance	Central Gas Furnace	Gas Wall Furnace	Free Standing Gas Heater	Gas Water Heater	Gas Cooktop	Gas Oven	Gas Clothes Dryer	Gas Fireplace	None	Don't Know
	2433 (88%)	61 (2%)	112 (4%)	2470 (89%)	2543 (92%)	1695 (61%)	2344 (85%)	2002 (72%)	21 (0.7%)	37 (1%)
Location of Gas Furnace	Attic	Basement or Crawl-space	Attached Garage	Interior Closet	Other Space (Inside Home)	Other Space (Outside Home)	Don't Know	NA		
	1765 (73%)	12 (0.5%)	278 (11%)	57 (2%)	29 (1%)	62 (2.5%)	145 (6%)	85 (3%)		
Location of Water Heater	Attic	Basement or Crawl-space	Attached Garage	Interior Closet	Other Space (Inside Home)	Other Space (Outside Home)	Don't Know	NA		
	23 (1%)	12 (0.5%)	2159 (87%)	42 (2%)	20 (1%)	119 (5%)	12 (0.5%)	83 (3%)		
Location of Clothes Dryer	Laundry Room	Basement or Crawl-space	Attached Garage	Interior Closet	Other Space (Inside Home)	Other Space (Outside Home)	Don't Know	NA		
	2100 (90%)	1 (<0.01%)	77 (3%)	59 (2.5%)	31 (1.3%)	0	1 (<0.01%)	75 (3%)		

Parameter	Survey Response Counts (%)									
Mechanical Ventilation System	Kitchen Range Hood	Kitchen Exhaust Fan	Bathroom Exhaust Fan	Continuous Exhaust Fan	Fresh Air Vent	Heat/ Energy Recovery Ventilator	Whole House Fan	Radon Control System	None	Don't Know
	2516	232	2521	113	640	38	504	32	20	113
	(91%)	(8%)	(91%)	(4%)	(23%)	(1%)	(18%)	(1%)	(1%)	(4%)
Particle Air Filter in Central Forced Air System	Yes	No, system does not have a particle air filter	No, does not have a central forced air heating system	Don't Know	NA					
	2103	108	10	321	229					
	(76%)	(4%)	(0.3%)	(12%)	(8%)					
Particle Air Filter Type	Tradition-al, Inexpensive Filter	Medium Efficiency Filter	High Efficiency Filter	Electro-static Filter	Other	Don't Know	NA			
	725	635	482	99	10	150	2			
	(34%)	(30%)	(23%)	(5%)	(0.5%)	(7%)	(<0.01%)			

Figure 1 to Figure 6 compare some of the basic house characteristics by year built. Homes are grouped into three year-built categories: 2002-2005, 2006-2010, and 2011-2015. Note that only 1 % (28) of homes were built after 2011. Figure 1 shows an increase in mean floor area between 2002 and 2008, and again from 2009 onwards, with a drop between 2008 and 2009 (likely related to 2007 housing market crash). The mean floor area for the three year built-categories show an increasing trend: 2,530 ft² for 2002-2005, 2,630 ft² for 2006-2010, and 2,760 ft² for 2011-2015. Figure 2 shows that there are slightly more multi-story homes built after 2011 in our survey compare to older homes, partly because there are proportionally more multi-story townhomes represented in the 2011–2015 year built group. Most homes have between 2 and 4 occupants (Figure 3) regardless of year built.

Figure 1 Mean floor area of homes built in different years. The red and blue dotted lines show mean floor area of homes built 2002-2005 and 2006-2010, respectively.

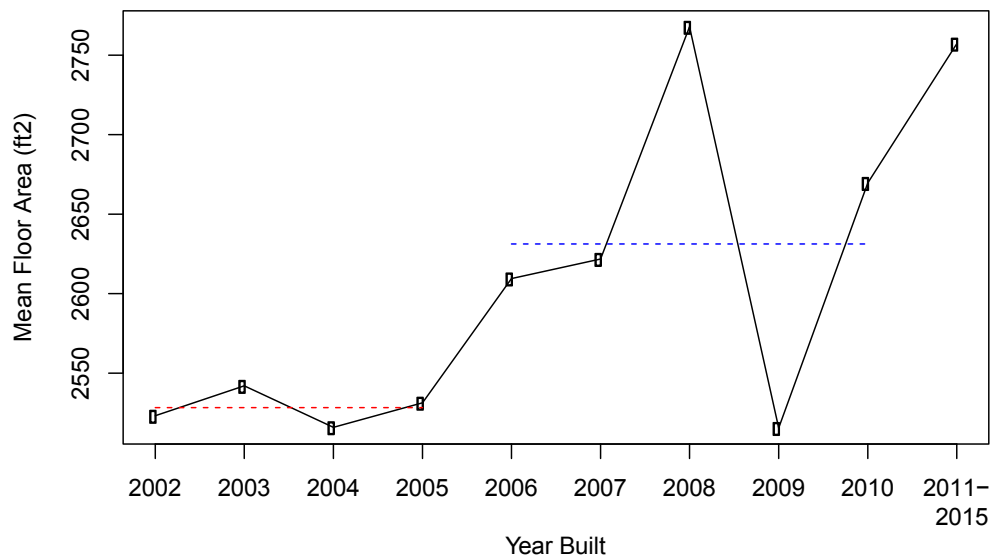


Figure 2 Number of stories of homes built in different years.

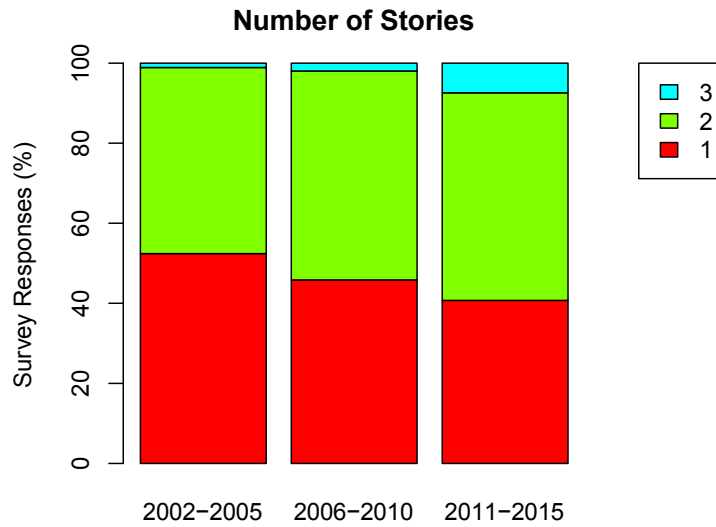
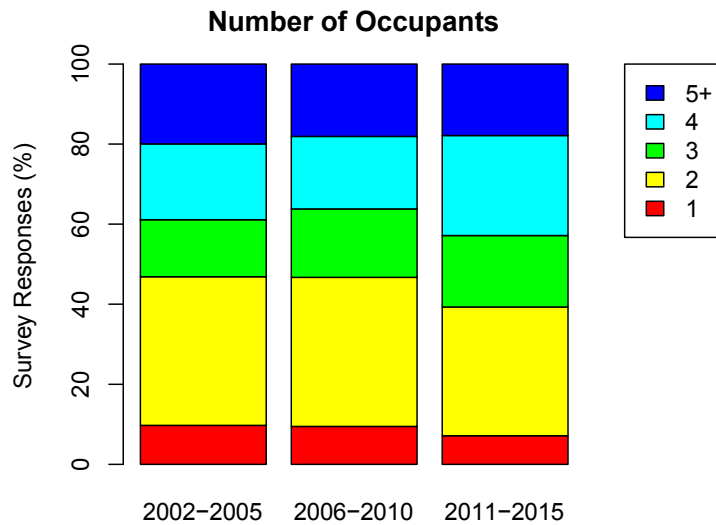


Figure 3 Number of occupants currently living in surveyed homes built in different years.



The prevalence of using natural gas for space heating, water heating, cooking (cooktop), and clothes drying are about the same regardless of year built (Figure 4). "NA" in Figure 4 represents all responses that did not reply "Yes" to the question whether a home has a particular natural gas appliance. "NA" can mean that a home does not have that particular appliance, or the appliance use alternate fuel other than natural gas. Responses that selected "None" or "Don't know" as the answer when asked to list gas appliances present in their homes are excluded from this comparison.

Kitchen range hood and bathroom exhaust fans are commonly found in the surveyed homes regardless of year built; the other mechanical ventilation equipment is less common (“NA” can mean that a home does not have that mechanical ventilation equipment, or home owners answered they do not know whether they have it or not). Figure 5 did not include a comparison for heat or energy recovery systems (H/ERV) or radon control systems because very few surveyed homes were reported to have them. Continuous exhaust fans, fresh air vents, and whole house fans are slightly more common among homes built after 2011 compared to other homes. Figure 6 shows that similar types of particle filters are reported being used in the central forced air system in surveyed homes regardless of year built. About 20% of survey respondents selected fresh air vent as part of their mechanical ventilation system. In the survey, a photo (see Appendix A-2) that shows a fresh air vent connected to heating and cooling system was provided to help illustrate what it may look like.

Figure 4 Presence of gas appliances in surveyed homes built in different years.

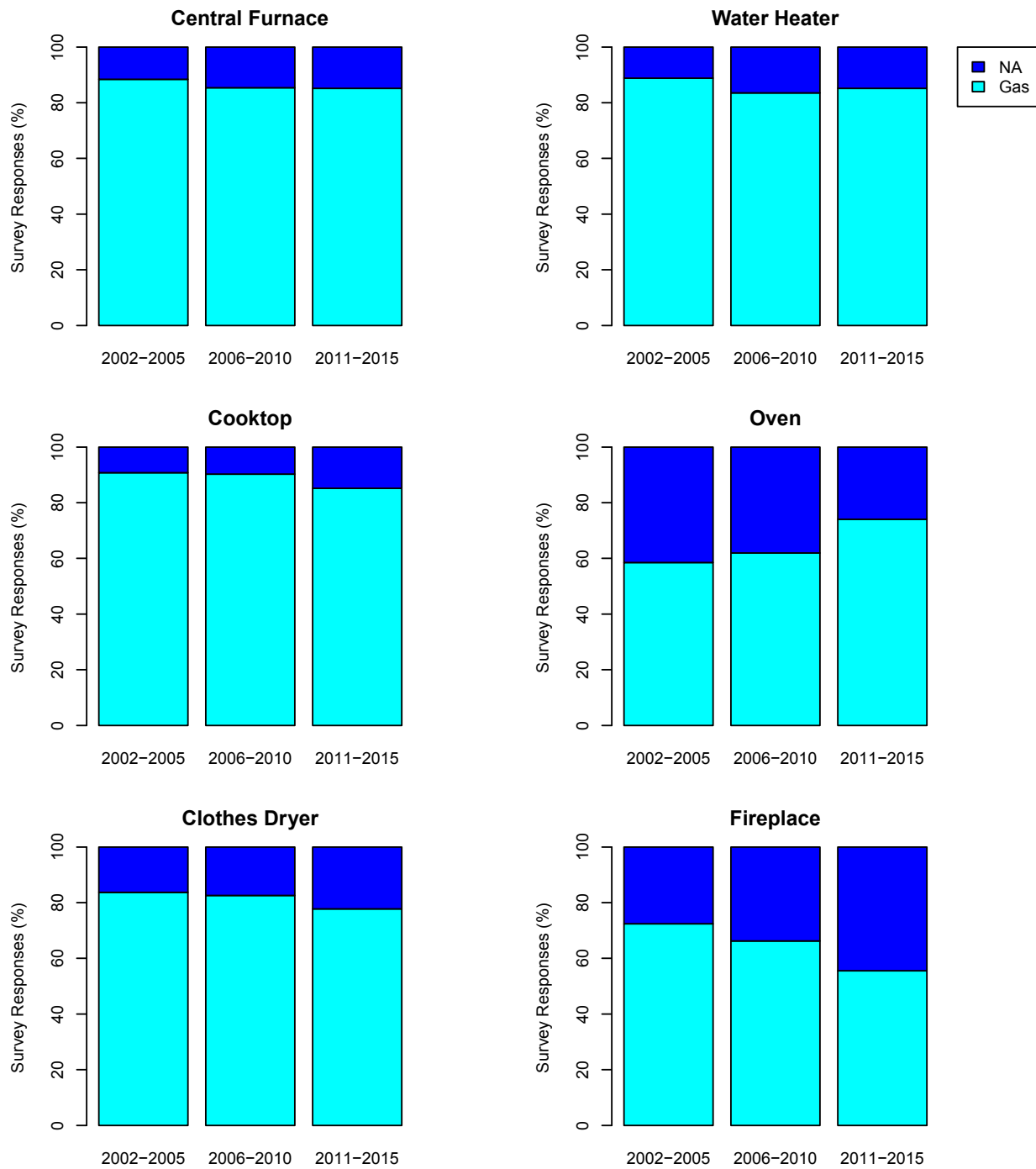


Figure 5 Presence of mechanical ventilation equipment in surveyed homes built in different years.

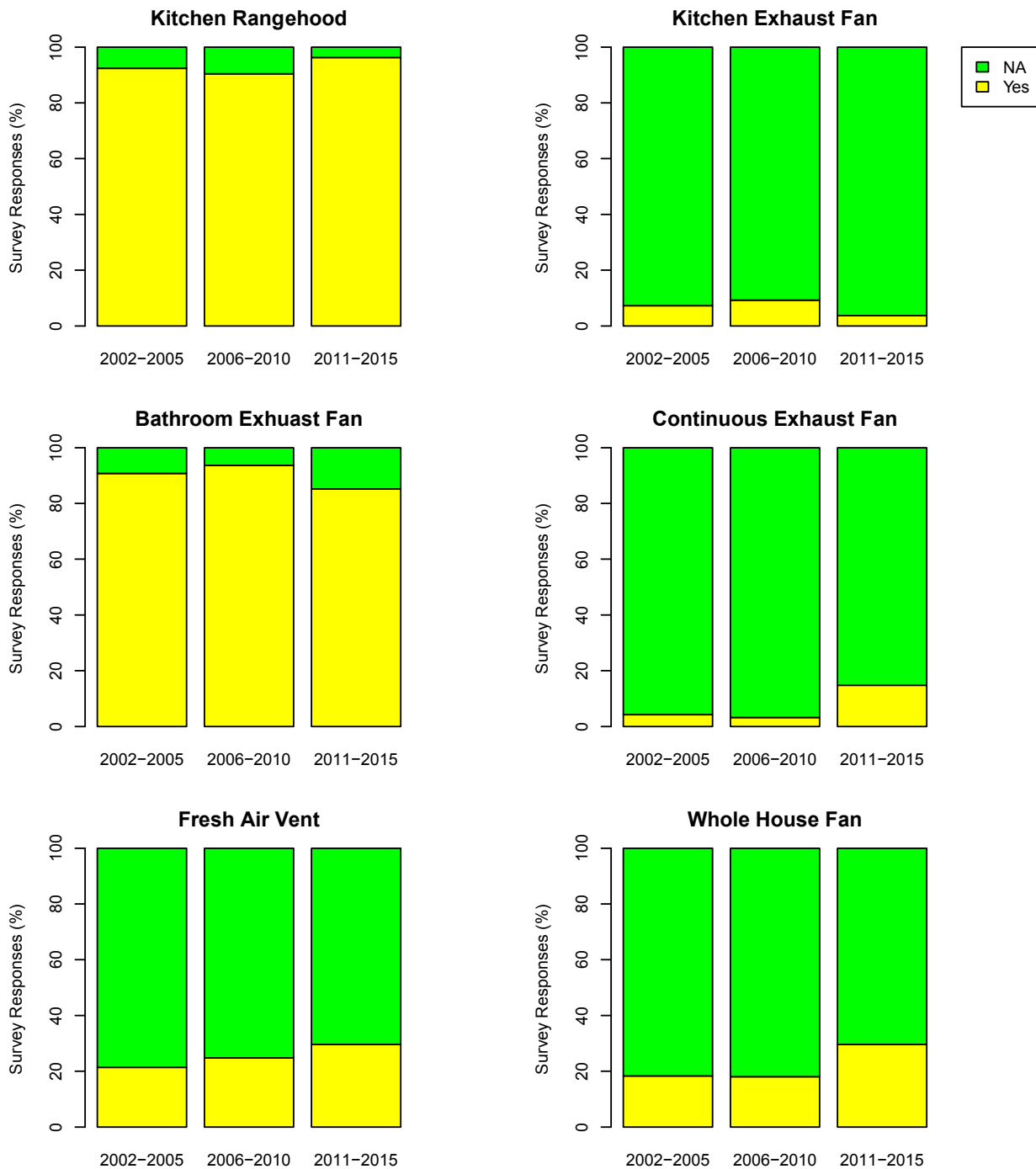
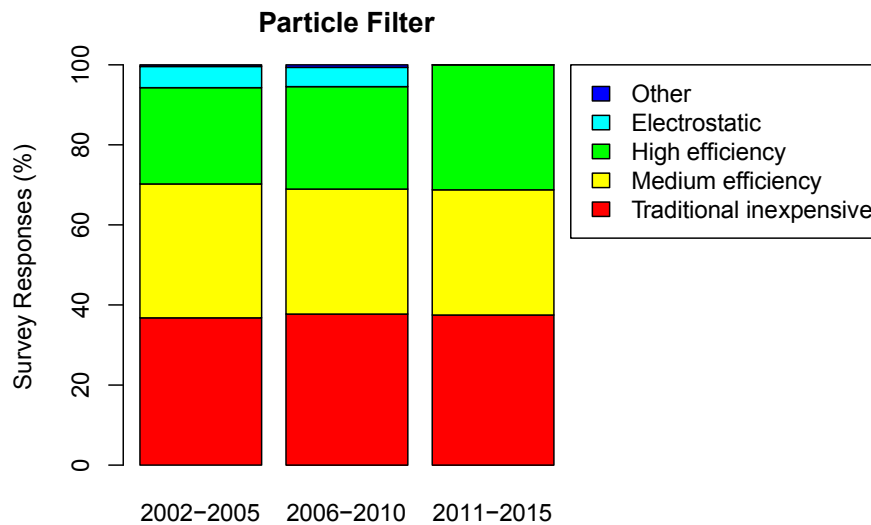


Figure 6 Particle filter types used in central forced air system in surveyed homes built in different years.

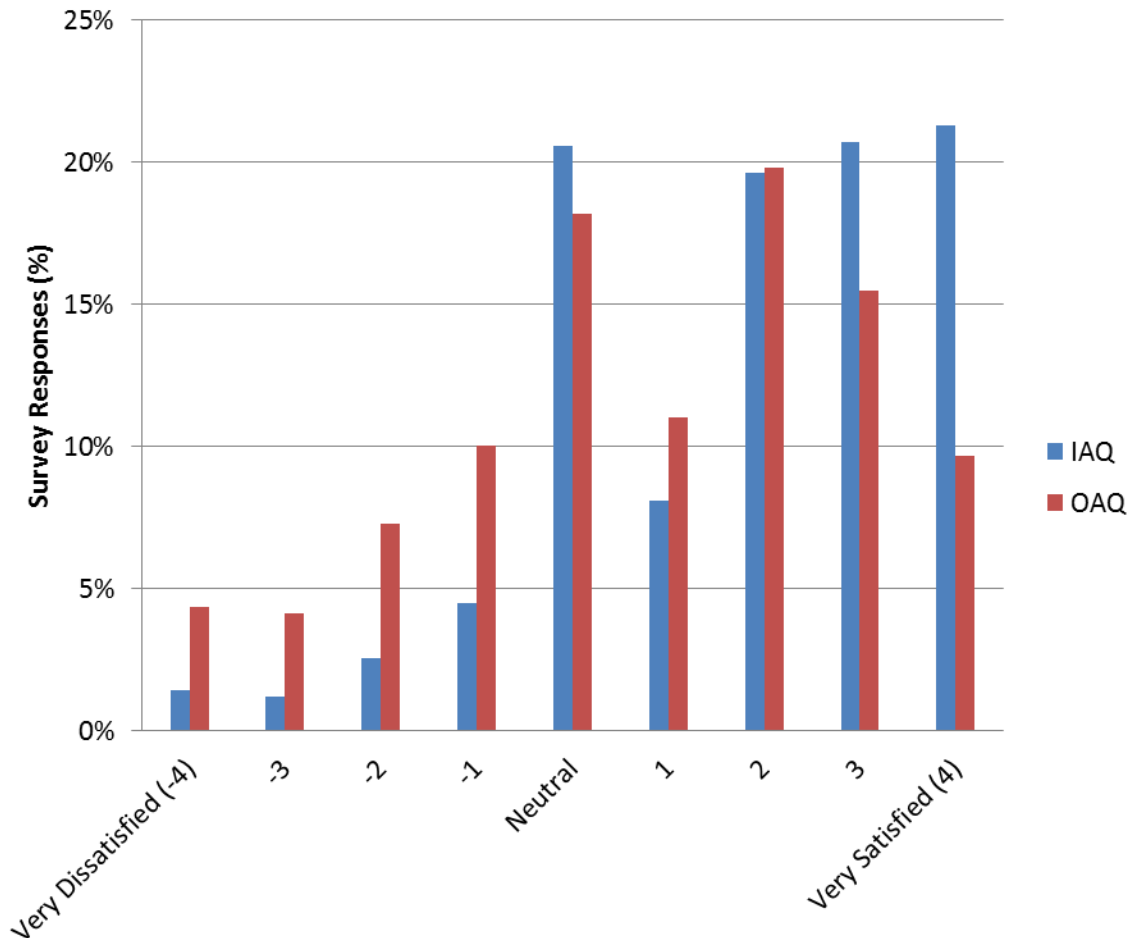


3.2 Occupant Satisfaction with Air Quality and Comfort

3.2.1 Occupant Satisfaction with Outdoor and Indoor Air Quality

Survey respondents were asked to rate their satisfaction with indoor and outdoor air quality. Results are summarized in Figure 7 (see Appendix A-3 for detailed statistics). Survey respondents were generally more satisfied with the indoor air quality in their home than the outdoor air quality near where they live. Twice as many survey respondents were very satisfied (rating = 4) with their indoor air quality (21%), compared to only 10% who were very satisfied with the outdoor air quality. Dissatisfaction (rating <0) with outdoor air quality (26%) is more common than dissatisfaction with indoor air quality (10%).

Figure 7 Occupant satisfaction on indoor air quality (IAQ, N=2,765) and outdoor air quality (OAQ, N=2,766).



3.2.2 Occupant Satisfaction with Comfort

In addition to satisfaction with indoor and outdoor air quality, the survey also gathered data on occupant satisfaction on comfort related to thermal conditioning, air movement, and moisture in their home. Survey respondents were asked the frequency that any occupants felt uncomfortable with air temperature in winter and summer, too much or not enough air movement, air too dry or too damp, or air has musty odor. Appendix A-3 has more detailed statistics of the results.

Figure 8 shows that the most common complaint with regard to thermal comfort is some room(s) being too hot in the summer: 41% of study participants complained that some room(s) are too hot in the summer a few times a week or more often, compared to 20% of study participants who complained of some room(s) being too cold in the winter. Survey respondents were also asked if some room(s) were too warm in the winter or too cool in the summer, which may suggest poor control or distribution of thermal conditioning to different rooms in the house. Only 10% of survey respondents indicated this to be an issue a few times a week or more frequently in either the heating or cooling season (“NA” can mean that the participant did not answer for this question: 3-10% of participants did not answer for this question).

Figure 8 Occupant satisfaction with thermal comfort in their homes.

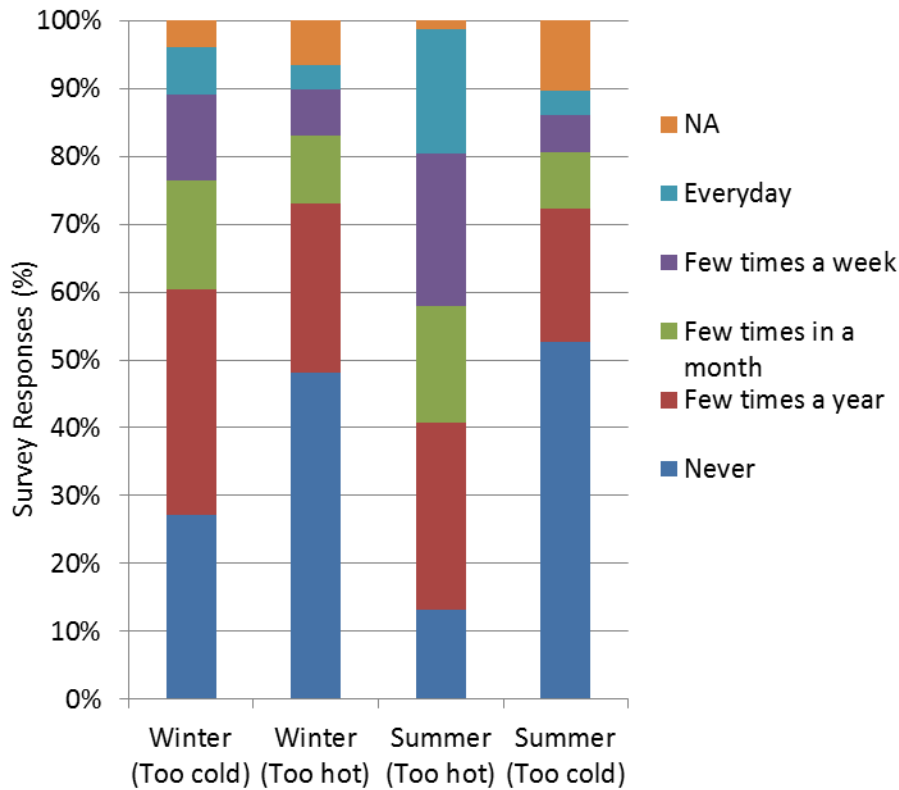
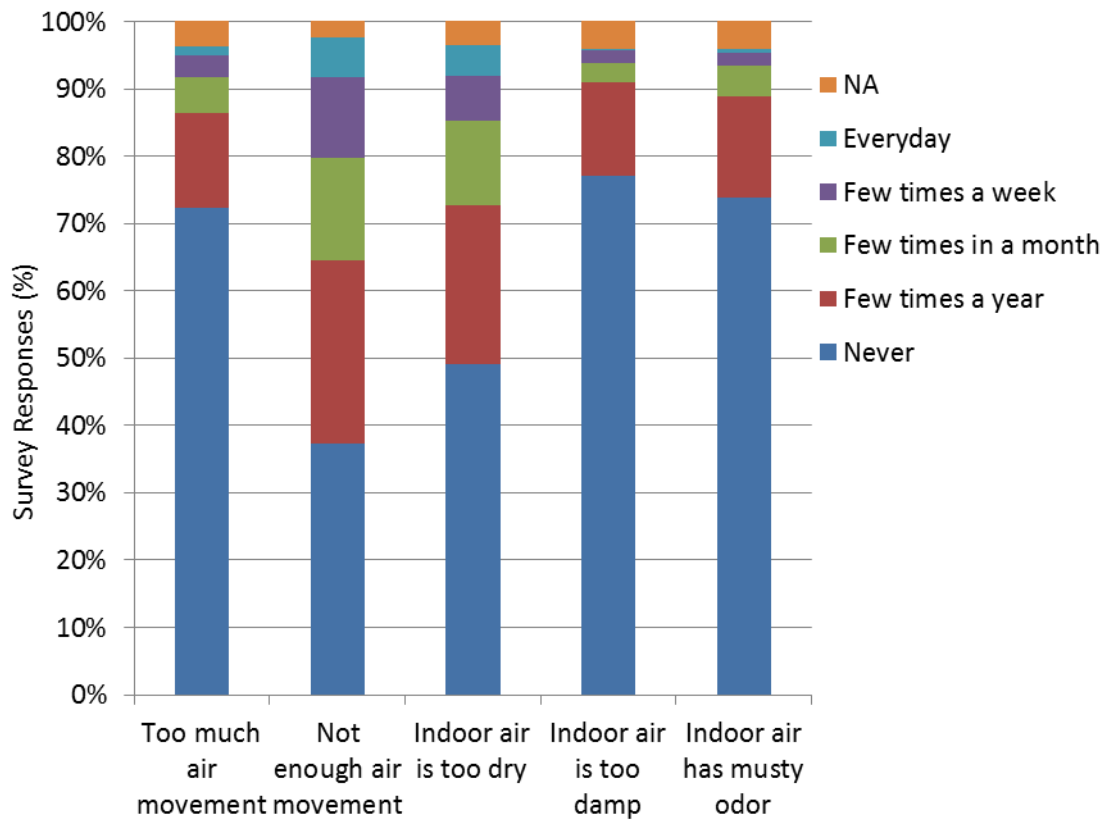


Figure 9 shows that more survey respondents complained about stagnant air (not enough air movement) than draftiness (too much air movement) in their homes. 18% of the responses indicated that stagnant air affects comfort in their home a few times a week or more frequently. Occupants are generally satisfied with the moisture level in their homes. About 12% of survey respondents complained that indoor air is too dry a few times a week or more frequently. Few homes (2%) had excess moisture that adversely impacted the comfort of the survey respondents (“NA” can mean that the participant did not answer for this question: 2 -4% of participants did not answer for this question).

Figure 9 Occupant satisfaction with indoor air movement and moisture level in their homes.



3.2.3 Factors Associated with IAQ Satisfaction

Table 5 to Table 7 summarize results from ordinal logistic regression performed to characterize the relationship between occupant indoor air quality satisfaction and three sets of explanatory variables: (i) house and household characteristics, (ii) thermal comfort, and (iii) indoor environmental conditions associated with air movement and moisture level.

In the survey, self-reported IAQ satisfaction questions used a 9-point scale with endpoints ranging between “very dissatisfied” and “very satisfied.” The actual question from the survey is shown below.

IAQ satisfaction: To what extent are you satisfied or dissatisfied with the indoor air quality in your home?

Very Dissatisfied				Neutral				Very Satisfied
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

For comfort satisfaction, the survey asked how often does anyone in the home feel uncomfortable in because of temperature, air movement and dryness. A 5-point scale with endpoints ranging between “Never” and “Every day” is used, as shown below.

Thermal comfort: In winter, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times in a month	Few times a week	Every day
Too hot in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Too cold in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

In summer, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times a month	Few times a week	Every day
Too hot in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Too cold in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Indoor environmental conditions: How often do the following conditions affect the comfort of occupants in your home?

	Never	Few times a year	Few times a month	Few times a week	Every day
Too much air movement.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Not enough air movement.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Indoor air is too dry.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Indoor air is too damp.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Indoor air has musty odor.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

For house characteristics, the survey asked respondents to provide the house size and number of occupants. Also, the survey asked the respondent to indicate which ventilation equipment was present from a list that included fresh air vent, continuous operating ventilation exhaust

fan, kitchen exhaust fan, bathroom exhaust fan, HRV (Heat Recovery Ventilator) or ERV (Energy Recovery Ventilator), Whole house fan, Radon control system and others.

Regression results are presented in terms of proportional odds ratios (OR), which quantify the odds of increasing IAQ satisfaction by one rating unit (e.g., from 0 to 1, from 1 to 2, etc.) as a result of one unit increase in each of the explanatory variables (e.g., for this analysis, never = 0, few times a year = 0.1, few times a month = 1, few times a week = 3, every day = 7). The results, provided in Table 5, shows that the number of occupants and the presence of fresh air vent are the parameters that have a p-value <0.05 (highlighted in bold font) associated with IAQ satisfaction. p-value <0.05 is used to test the null hypothesis that OR = 1 (i.e. no effect). OR = 0.87 means that each additional occupant would change the odds of increasing IAQ satisfaction by one rating unit by 0.87, i.e. increasing number of occupants in household would likely decreases the overall IAQ satisfaction. The 95% confidence interval for this OR is between 0.83 and 0.90. Neither floor area nor number of stories is statistically associated with IAQ satisfaction. Survey respondents, who answered that they have a fresh air vent reported higher ratings with indoor air quality satisfaction (OR = 1.46). But the survey respondents who answered that they have a continuous exhaust fan did not show statistically significant associations with IAQ satisfaction. This is interesting since the purpose of the fresh air vent and the continuous exhaust fan is basically the same: they are used to provide air exchange with the outdoors. However, it is possible that survey respondents can associate the words “fresh air vent” with IAQ more than a “continuous exhaust fan”. This can be an endemic issue with surveys that rely on occupants to report on equipment. The potential that a respondent will subconsciously link the terms may be reduced by having these questions separated in the survey. Also, the order of the questions could be reversed, such that IAQ satisfaction is determined prior to priming respondents with the term ‘fresh air’. Alternatively, a neutral term could be used to describe the central fan integrated system (e.g., outside air intake on central HVAC).

Table 6 and Table 7 show that thermal comfort and indoor environmental conditions likely have an effect on occupant ratings of IAQ satisfaction.

Table 6 shows that the frequency of discomfort because of some room(s) being too hot in summer (OR=0.85), and some room(s) being too cold in winter (OR=0.94), are both negatively associated with IAQ satisfaction. Table 7 shows that discomfort because of musty odor lowers the odds of IAQ satisfaction (OR=0.70). Other factors that are also negatively associated with IAQ satisfaction include not enough air movement (OR = 0.80) and indoor air being too dry (OR = 0.86). Factors that suggest more potential sources of indoor pollutants (e.g., number of occupants) and increasing the discomfort of odor issues (e.g., musty odor) are negatively associated with IAQ satisfaction ratings. Musty odor is likely a result of persistent dampness in the home. However, a higher reported frequency of from indoor air being too damp does not have a statistically significant association with occupant rating of IAQ satisfaction (Table 7). This may be because occupants do not perceive excess moisture or dampness as a reason for causing discomfort, unlike musty odor. The previous California new home study also found similar results: i.e., that people expect and are willing to accept a certain amount of moisture and discomfort and do not consider these to be unacceptable for overall IAQ satisfaction (CEC, 2007).

Table 5 Odds ratios of IAQ satisfaction improving with specific house or household characteristic.

House or Household Characteristics	Indoor Air Quality Satisfaction (N=2,686)			
	Odds Ratio	95% Confidence Interval		p-value
		2.5%	97.5%	
Floor area*	1.11	0.64	2.17	0.64
Number of stories	0.96	0.85	1.09	0.57
Number of occupants	0.87	0.83	0.90	3e-10
Presence of fresh air vent	1.46	1.24	1.72	4.3e-06
Presence of continuous exhaust fan	1.13	0.79	1.62	0.50

*Floor area was divided by 929 m² (10,000 ft²) to transform to a dimensionless parameter in this analysis.

Table 6 Odds ratios of thermal comfort on indoor air quality satisfaction.

Thermal Comfort	Indoor air Quality Satisfaction (N=2,718)			
	Odds Ratio	95% Confidence Interval		p-value
		2.5%	97.5%	
Winter (Too cold in some rooms)	0.94	0.89	0.99	1.2e-02
Winter (Too hot in some rooms)	0.95	0.89	1.01	0.11
Summer (Too cold in some rooms)	0.96	0.90	1.02	0.24
Summer (Too hot in some rooms)	0.85	0.82	0.88	1.7e-22

Table 7 Odds ratios of indoor environmental conditions on indoor air quality satisfaction.

Indoor Environmental Conditions	Indoor air Quality Satisfaction (N=2,578)			
	Odds Ratio	95% Confidence Interval		p-value
		2.5%	97.5%	
Too much air movement	1.01	0.93	1.09	0.85
Not enough air movement	0.80	0.76	0.83	1.3e-24
Indoor air is too dry	0.86	0.82	0.90	1.34e-09
Indoor air is too damp	0.94	0.80	1.11	0.50
Indoor air has musty odor	0.70	0.62	0.79	3.49e-09

3.3 Kitchen Ventilation

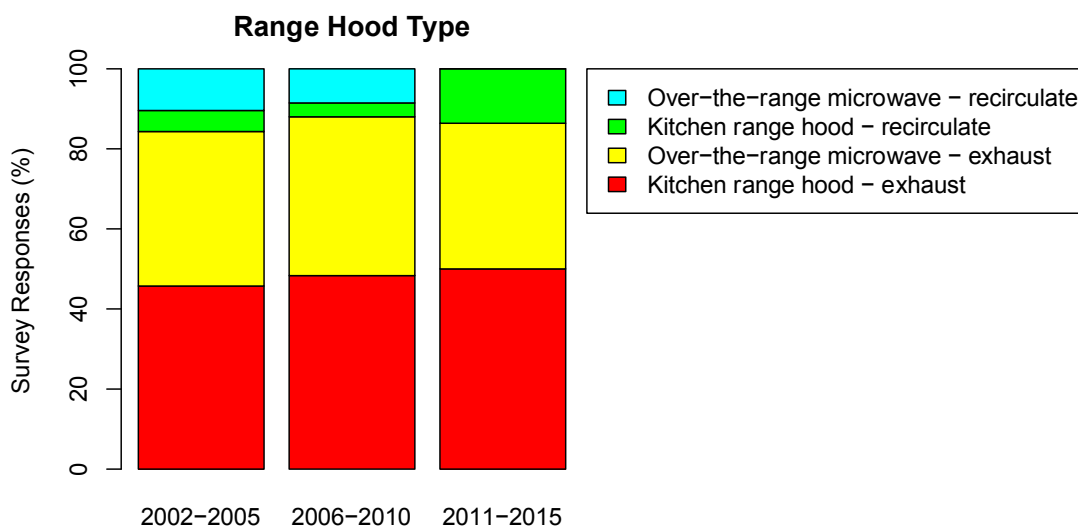
3.3.1 Kitchen range hood types and usage

Survey respondents were asked to identify the type of range hood they have and the frequency of usage. Table 8 shows that a kitchen range hood that exhausts air to the outside is the most common type (43%), followed by an over-the-range microwave that exhausts air to outside (33%). Less common are kitchen range hoods and over-the-range microwaves that recirculate air back into the kitchen (4% and 8%, respectively). Figure 10 shows a slight increase in kitchen range hood that exhausts air to outside comparing homes built 2006-2010 to homes built 2002-2005. Results of the newest year built group (2011-2015) are more uncertain because of the small sample size (N=28) and based on Title 24 (2008), all of these homes should have a kitchen range hood that exhausts air to the outside.

Table 8 Types of range hood present in surveyed homes (N = 2,516).

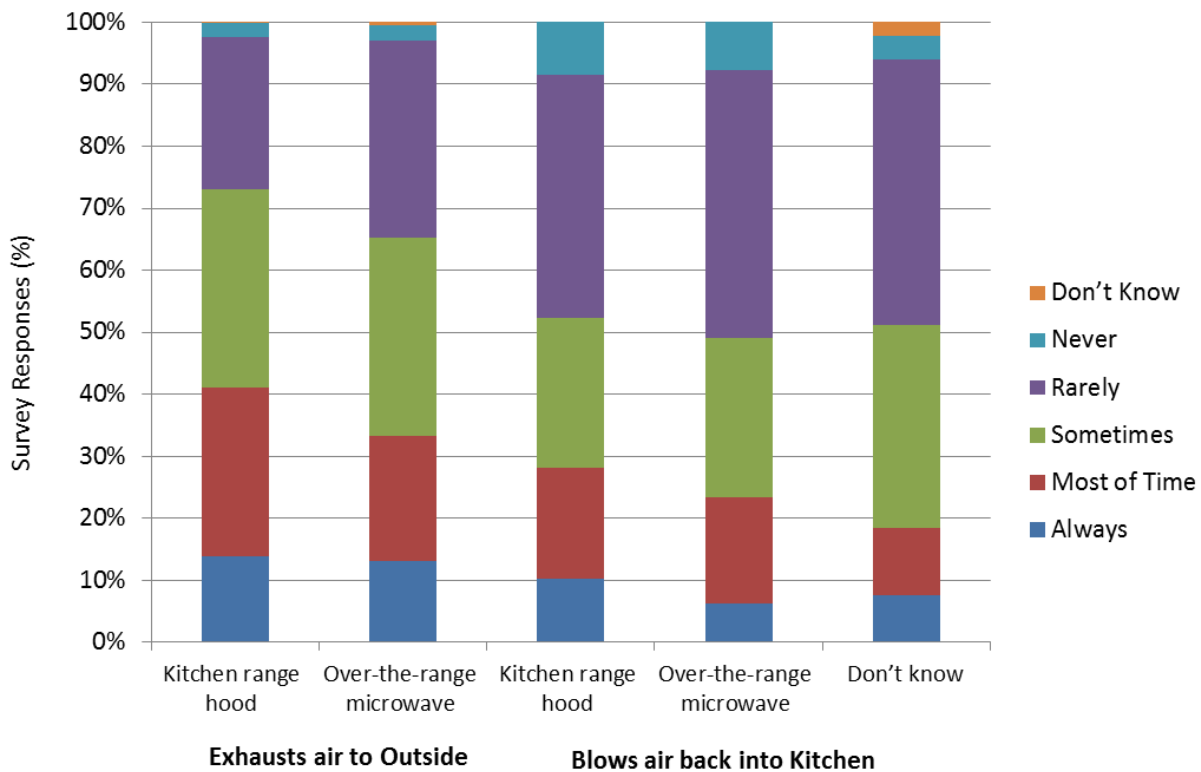
Parameter		Survey Response				
		Counts (%)				
Range Hood Type	Kitchen range hood exhausts air to outside	Kitchen range hood blows air back into kitchen	Over-the-range microwave exhausts air to outside	Over-the-range microwave blows air back into kitchen	Don't know	NA
	1081	107	901	222	131	74
	(43%)	(4%)	(33%)	(8%)	(5%)	(3%)

Figure 10 Kitchen range hood type in homes built in different years (these are percentages of participants who answered other than “don’t know”)



Survey respondents were asked how often the kitchen range hood is used when cooking with a cooktop. Figure 4 shows that survey respondents who had a range hood that vents to the outside reported using their range hood more frequently than those who had a recirculating range hood. This could reflect occupants observing that the venting range hood is more effective in dealing with pollutants, heat and moisture emitted during cooking. See Appendix A-3 for more detailed statistics on range hood usage frequency.

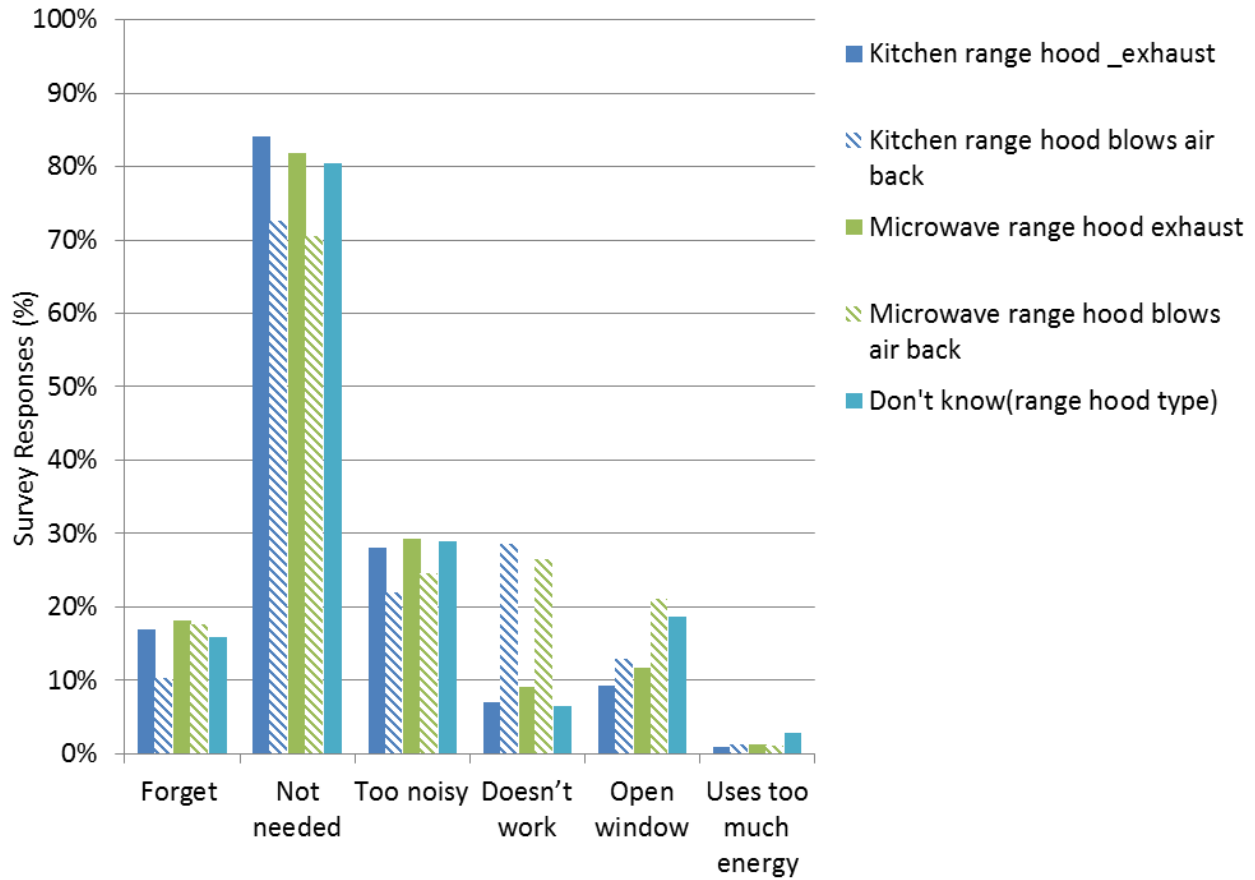
Figure 11 Frequency of the kitchen range hood usage.



Survey respondents who indicated that they use the range hood sometimes or less frequently were asked the reasons for not using the range hood. The respondents could choose more than one answer if applicable. Figure 12 shows that the most common reason for not using the range hood is “not needed for what is being cooked”. This suggests that users are making an assessment of the need, presumably based on some observable indicator such as odor, excess moisture, heat or smoke. Range hood being too noisy and forgetting to turn on range hood were other explanations indicated by respondents for not using the range hood; but there were relatively minor compared to the perception that the range hood is not always needed when cooking. Energy use by the range hood was not a common concern among users.

Almost 25% of survey respondents with a recirculating range hood indicated that they do not use their range hood because it is ineffective at removing cooking fumes or odors. In comparison, less than 10% of survey respondents who with a venting range hood indicated that as a reason for not using it. This difference by range hood type suggests that users are aware that range hoods that vent to outside are more effective at removing cooking fumes or odors than ones that blow air back into the kitchen. This may also explain why a relatively higher percentage of survey respondents who have a range hood that blows air back into the kitchen open their windows instead when they cook.

Figure 12 Reasons not for using range hood when cooking with cooktop.



3.3.2 Factors Associated with Range Hood Use

An ordinal logistic regression was performed to characterize whether kitchen range hood types and frequency of cooktop use have statistical significance on range hood use frequency. Survey respondents were asked the frequency of cooktop use for preparing breakfast, lunch, dinner and other meals. The total number of cooktop uses per week was estimated by summing all meals prepared. For self-reported frequency of cooktop usage, a 5-point scale with endpoints ranging between “0 time per week” and “7 times per week” is used, as shown below.

On average, how many times per week is your cooktop and/or oven used for cooking, including boiling water?

	0 time per week	1 to 2 times per week	3 to 4 times per week	5 to 6 times per week	7 times per week
Breakfast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lunch	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dinner	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other cooking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

The regression result is shown in Table 9. Range hood use is positively correlated with the cooking frequency (OR=1.05, P<0.05). As suggested by the comparison shown in Figure 11, range hood types also had statistically significant effects on the frequency of the range hood usage. The frequency of range hood use is reduced when survey respondents indicated that they have a range hood that blows air back to the kitchen (OR = 0.37), or they have an over-the-range microwave range hood that blows air back to the kitchen (OR = 0.46). Survey respondents who do not know the type of range hood they have may be less familiar with their appliance because of infrequent use, so it makes sense that range hood use frequency tends to be lower if the range hood type is unknown.

Table 9 Odds ratios of cooking activity and range hood type on range hood use frequency.

Cooking Activity and Range Hood Type	Range Hood Use Frequency (N=2,561)			
	95% Confidence Interval			p-value
	OR	2.5%	97.5%	
Cooking Frequency (Total Number of Meals per Week)	1.05	1.04	1.07	6.8e-16
Range Hood (Exhaust)	1.09	0.75	1.6	0.64
Range hood (Recirculate)	0.37	0.21	0.65	5.6e-04
Microwave Range Hood (Exhaust)	0.78	0.53	1.16	0.22
Microwave Range Hood (Recirculate)	0.46	0.29	0.73	9.6e-04
Don't Know (Type Unknown)	0.44	0.26	0.75	0.003

3.4 Bathroom Ventilation

Survey respondents were asked about the type(s) of bathroom exhaust fan control they have in their homes. Table 10 shows that the most common control was a manual on/off switch. Automatic controls, such as a timer, humidity sensor, and/or occupancy sensor were less common overall. The 2008 Title 24 requirements for intermittent local exhaust ventilation do not specify what type of control is used, only that there is a control. Specific controls are specified by some programs, such as the 2013 CalGreen building code which required that bathroom fans must be controlled by a humidistat.

Table 10 Bathroom exhaust fan control type.

Bathroom Exhaust Fan Control Type	Full Bathroom (N = 2,736)	Half Bathroom (N = 1,112)
Auto-on timer control	84 (3%)	28 (3%)
Auto-on humidity sensor	30 (1%)	1 (0.1%)
Auto-on occupancy sensor	23 (1%)	11 (1%)
Comes on when light is turned on	267 (10%)	82 (7%)
Manual on/off switch	2168 (79%)	831 (75%)
On all the time	9 (0.3%)	8 (0.7%)
No exhaust fan	182 (7%)	44 (4%)
NA	316 (12%)	119 (11%)

Figure 13 shows the percentage of homes with automatic bathroom exhaust fan control (left), and homes with manual control (right) in at least one of the full bathroom. Automatic control includes bathroom exhaust fans that are controlled by a timer, humidity sensor, and/or occupancy sensor. Manual control includes bathroom exhaust fans that are controlled by a manual on/off switch, and also those that come on when light is switched on. Survey respondents were asked to enter the number of full bathrooms having each of the control types, meaning that it is possible for homes to have some full bathrooms with automatic control, other full bathrooms with manual control, and/or full bathrooms with both types of control (i.e. the sum of automatic and manual control may not equal 100%). Only homes that the survey respondents indicated presence of an exhaust fan in at least one of their full bathrooms are included in this comparison. Figure 13 shows that while many bathroom exhaust fans are manually controlled, such as by an on/off switch, automatic controls are becoming more common in newer homes.

Figure 13 Bathroom exhaust fan control type in homes built in different years.

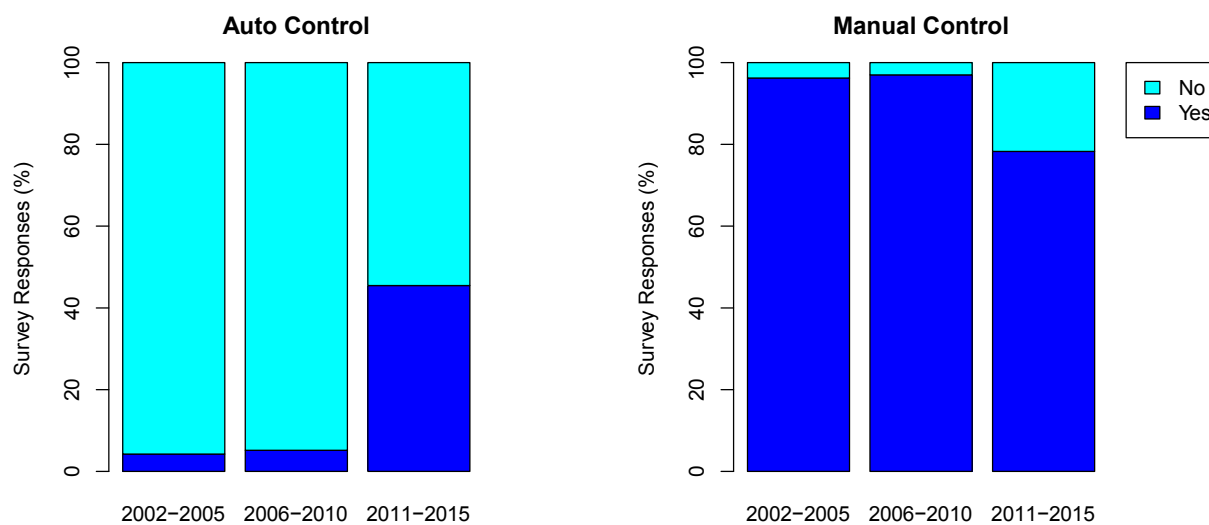


Table 11 shows the ordinal logistic regression results of selected house characteristics, including the number of bathroom exhaust fans, on survey respondents reported frequency of discomfort from musty odor in their homes. Results suggest that there is a negative association ($OR < 1$) between number of bath fans and frequency of discomfort due to musty odor ($OR=0.94$, $P<0.05$). On the other hand, increasing the number of occupants has a positive association ($OR > 1$) with the frequency of discomfort from musty odor in their homes ($OR=1.18$, $P<0.05$). These results suggest that bathroom exhaust fans may be helpful to reduce the frequency of musty odor causing discomfort in homes, whereas more occupants is a risk factor. To keep this analysis simple, the number of bathroom exhaust fans was not normalized by number of bathroom or floor area. Instead, floor area is included as one of the explanatory variables. However, floor area is not found to be statistically significant in this regression analysis. The number of occupants normalized by floor area is also not statistically associated with the frequency of discomfort from musty odor.

Table 11 Odds ratios of selected house characteristics on frequency of discomfort from musty odor.

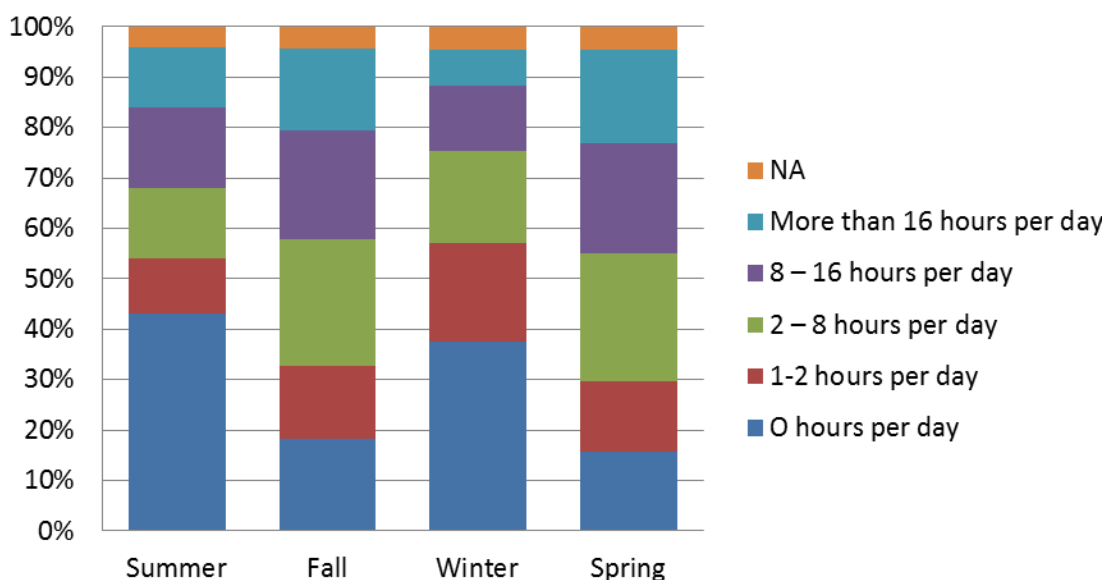
	Musty odor (N=2,622)			
	OR	95% Confidence Interval		p-value
		2.5%	97.5%	
Floor Area*	0.58	0.28	1.22	0.16
Number of occupants	1.18	1.11	1.24	3e-09
Number of bath fans	0.94	0.88	0.99	1.99e-02

*Floor area was transformed to a dimensionless parameter by a division of 929 m² (10,000 ft²).

3.5 Window Opening

Survey respondents provided the number of hours per day on average they opened their windows in each of the four seasons. Survey respondents were asked “how many hours per day are your windows open?” The survey did not ask the number of windows open or the size of the openings. Results are summarized in Figure 14; see also Appendix A-3 for detailed statistics. In summer and winter, 43% and 38% of the people never open the windows, compared to 18% and 16% in fall and spring. In fall and spring, the majority of households (70%) opened their windows for at least 2–8 hours per day. In summer and winter, about 40% of people opened their windows for at least 2–8 hours per day. Compared to a previous study (CEC, 2007), in the fall and spring season, the results are similar but in summer, the previous study found more window opening. A previous LBNL study (Price and Sherman 2006) found broadly similar results with slightly more summer window opening, but less in the winter. Most of the survey respondents are located in southern California which is a hot and dry climate that may have an influence on window opening behavior because the previous studies collected the data from more diverse area.

Figure 14 Window opening frequency by season.



3.5.1 Correlation between window openings with IAQ/OAQ satisfaction

Table 12 shows regression results of IAQ and OAQ satisfaction predicting window opening. The result showed that except winter, the hours of window openings in all other seasons are statistically significant with regard to the satisfaction of OAQ ($OR_{spring} = 1.08$, $OR_{summer} = 1.18$ and $OR_{fall} = 1.08$, $P < 0.05$). This suggests that survey respondents who rated OAQ positively would open their window more often, or in other words those who rated OAQ negatively would open their window less often. In comparison, the association between window openings and IAQ satisfaction is less clear, with OR_{winter} being the only statistically significant result. In winter, the negative association ($OR < 1$) suggests that survey respondents who rated IAQ poorly would open their windows more often.

Table 12 Odds ratios of indoor and outdoor air quality satisfaction associated with window opening frequency.

Satisfaction with Air Quality	Spring (N=2,571)				Summer (N=2,574)			
	OR	95% CI		p-value	OR	95% CI		p-value
		2.5%	97.5%			2.5%	97.5%	
Indoor air quality	0.97	0.93	1.01	0.09	0.97	0.93	1.01	0.10
Outdoor air quality	1.08	1.04	1.11	2.4e-05	1.18	1.13	1.22	7.3 e-18
	Fall (N=2,574)				Winter (N=2,574)			
	OR	95% CI		p-value	OR	95% CI		p-value
		2.5%	97.5%			2.5%	97.5%	
Indoor air quality	0.97	0.93	1.01	0.2	0.95	0.91	0.99	0.016
Outdoor air quality	1.08	1.04	1.12	1.6e-05	1.04	1.00	1.07	0.05

Table 13 shows the odds ratios of other indoor environmental parameters on window opening frequency. The results showed that for all four seasons, survey respondents' satisfaction with air movement was correlated with window opening. More frequent experience of not enough air movement was associated with more window opening and more frequent sensation of too much air movement was associated with less window opening, with both correlations appearing as statistically discernible in all seasons.

In the summer, survey respondents satisfaction with indoor air moisture level (Indoor air too dry, Indoor air too damp) is also statistically associated with window opening frequency. Survey respondents who perceived indoor air as too damp report opening windows more frequently. The other associations between indoor environmental conditions and window opening frequency are less clear statistically as indicated by the p-value close to 0.05. Collectively, these results are consistent with at least a fraction of the population using window opening to manage IAQ and comfort in a rational manner.

Table 13 Odds ratios of indoor environmental conditions on window opening frequency.

Indoor Environmental Conditions	Spring (N=2,571)				Summer (N=2,574)			
	OR	95% CI		p-value	OR	95% CI		p-value
		2.5%	97.5%			2.5%	97.5%	
Too much air movement	0.93	0.89	0.97	0.002	0.93	0.88	0.97	8.9 e-04
Not enough air movement	1.09	1.05	1.13	9.4e-08	1.05	1.02	1.08	0.003
Indoor air too dry	0.96	0.93	1.00	0.03	0.94	0.91	0.97	4.1e-04
Indoor air too damp	1.03	0.96	1.10	0.43	1.23	1.15	1.32	1.9e-09
Musty odor	0.97	0.91	1.02	0.22	0.94	0.89	1.00	0.04
	Fall (N=2,574)				Winter (N=2,574)			
	OR	95% CI		p-value	OR	95% CI		p-value
		2.5%	97.5%			2.5%	97.5%	
Too much air movement	0.94	0.90	0.98	0.005	0.94	0.89	0.98	3.8e-03
Not enough air movement	1.09	1.06	1.13	1.15e-07	1.07	1.04	1.10	3.8e-05
Indoor air too dry	0.98	0.95	1.02	0.36	1.02	0.98	1.05	0.33
Indoor air too damp	1.03	0.96	1.09	0.44	1.01	0.95	1.08	0.70
Musty odor	0.94	0.89	1.00	0.03	0.99	0.93	1.04	0.60

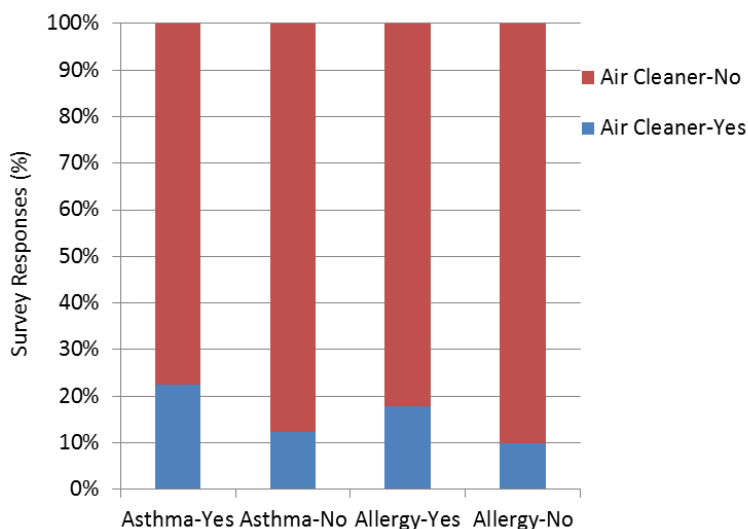
3.6 Use of air cleaners

Survey respondents were asked whether they use a stand-alone (portable) air filter, air purifier, or air cleaner in their homes. Only a small percentage (13%) of survey respondents reported using such a device, the majority of survey respondents (81%) do not (5% of survey respondents skipped this question, and 1% indicated they did not know the answer).

Survey respondents were also asked if anyone in the household has been diagnosed with asthma or allergies. Households with at least one person diagnosed with allergies are common: 53% of survey respondents reported at least one person has been diagnosed with allergies (41% reported no to this question), and 19% of survey respondents reported at least one person has been diagnosed with asthma (76% reported no to this question).

Figure 15 shows the percentage of survey respondents reporting the use of a stand-alone (portable) air filter, air purifier, or air cleaner in their homes, and comparing the percentages in households with and without at least one person diagnosed with asthma or allergy. The percentage of stand-alone (portable) air filter, air purifier, or air cleaner usage almost doubled in households with at least one person diagnosed with asthma or allergy compared to households without; see Appendix A-3 for detailed statistics.

Figure 15 Stand-alone (portable) air filter, air purifier, or air cleaner usage with and without at least one person in a household diagnosed of asthma or allergy.



3.6.1 Factors associated with air cleaner usage

Table 14 shows results of ordinal logistic regression of several factors that are potentially associated with use of an air cleaner in a household. As previously discussed, households that have at least one person diagnosed with asthma or allergies are more likely to use air cleaners. The odds ratios (allergy: OR=1.64, $P<0.05$; asthma: OR=1.55, $P<0.05$) in Table 14 quantify this positive association. In addition, satisfaction with outdoor air quality is also a factor that has statistical significance on air cleaner usage. The odds ratio (OR=0.92, $P<0.05$) suggests that survey respondents are more likely to use an air cleaner in their home if they give a lower rating on satisfaction with outdoor air quality. On the other hand, satisfaction with indoor air quality is not a statistically significant factor predicting air cleaner usage ($P=0.07$). These results suggest that poor outdoor air quality may be one of the factors why survey respondents use an air cleaner in their homes. The current survey did not ask survey respondents the reasons they use their air cleaner, so no cause-effect argument can be made. There are also numerous other possible reasons to use an air cleaner. For example, the perception of poor IAQ leads to air cleaner usage therefore it is expected to see a correlation between air cleaner usage and poor IAQ perception. However, it is possible that the air cleaner improved the IAQ, so the correlation between air cleaner usage and IAQ perception was not observed from the current survey.

Table 14 Odds ratios of diagnosis with allergy or asthma in household, satisfaction with indoor and outdoor air quality, on air cleaner usage.

Parameters	Air Cleaner Usage (N=2,543)			
	OR	95% Confidence Interval		p-value
		2.5%	97.5%	
Allergy	1.64	1.27	2.13	0.00016
Asthma	1.55	1.19	2.02	0.0012
Indoor air quality	0.94	0.88	1.00	0.07
Outdoor air quality	0.92	0.87	0.98	0.007

4 Summary

An occupancy survey was conducted to obtain information about mechanical ventilation characteristics and occupant satisfaction of new homes in California. This report summarizes survey data on house and household characteristics, such as the types of mechanical ventilation equipment and gas appliances installed (and how they are used), occupant satisfaction with IAQ and other indoor environmental parameters, and other occupant activities related to IAQ, e.g., window opening and use of an air cleaner. Most of our survey participants are SoCalGas company customers so most of them have gas appliances.

Most surveyed homes are single-family detached homes, built between 2002 and 2006. The majority of survey respondents are homeowners. Most homes have floor areas between 140 and 279 m² (1,500–3,000 ft²), and are occupied by two to four occupants. The majority of heads of household of the surveyed homes had a college or more advanced degree. Almost half of the household had a combined income of above \$100,000.

Most surveyed homes have a central gas furnace, gas water heater, and gas cooktop. Gas clothes dryer, gas oven, and gas fireplace are also common. Survey respondents indicated that most of them have a kitchen range hood and bathroom exhaust fans in their home. Most survey respondents indicated that they have a particle air filter in their central forced air system. Over half of the homes characterized the air filter as either a medium (MERV 8-11) or high (MERV \geq 12) efficiency.

A comparison of floor area, number of stories, number of occupants, types of gas appliances, mechanical ventilation systems, and particle air filter in the central forced air systems of homes were presented by year built: 2002–2005, 2006–2010, 2011–2015. Overall, homes are similar in terms of these characteristics. For the 28 homes built after 2011, there is a trend of slightly larger floor area in 2011–2015 homes, more homes with gas ovens, fewer homes with gas fireplace, and more homes with continuous exhaust fan, fresh air vent, and/or whole house fan. The latter are to be expected given the code changes requiring these mechanical ventilation systems.

In addition to summarizing the survey data, statistical analyses were performed to characterize potential associations between IAQ satisfaction, comfort, and health indicators with house and household characteristics. The health indicators were items such as, any person in household with diagnosed allergy and/or asthma. The household characteristics considered were floor area, number of occupants, kitchen and bathroom ventilation, window opening, and use of an air cleaner. Ordinal logistic regression was used to characterize the relationship between a set of explanatory variables and the response parameter.

Survey respondents were generally more satisfied with the indoor air quality in their home than the outdoor air quality near where they live. But because survey respondents tend to associate indoor air quality with other indoor environmental conditions, such as thermal comfort, air movement, and dryness, the term “indoor air quality” potentially has many meanings that could complicate interpretation of the survey data. The most common complaint with regard to thermal comfort is some room(s) being too hot in the summer. More survey respondents complained about stagnant air (not enough air movement) than draftiness (too much air movement) in their homes. Occupants are generally satisfied with the moisture level in their homes. Results from ordinal logistic regression suggest that potential sources of indoor pollutants (e.g., number of occupants) and odor issues (e.g., musty odor) are negatively associated with IAQ satisfaction ratings. Occupant IAQ satisfaction may be influenced by other indoor environmental conditions, such as thermal comfort, not enough air movement, and dryness.

Kitchen range hoods and over-the-range microwaves that exhaust air to outside are the most common types of kitchen ventilation. Survey respondents who have a range hood that is exhausted to the outside use their range hood more frequently than those who have a range hood that blows air back into the kitchen. Almost 25% of survey respondents who have a range hood that blows air back into the kitchen indicated that they do not use their range hood because they are ineffective at removing cooking fumes or odors. In comparison, less than 10% of survey respondents who have a range hood that is exhausted to outside indicated that as a reason for not using the range hood. The most common reason by far (75%) for not using the range hood is “not needed for what is being cooked”. Range hood being “too noisy” and “forget to turn it” are also some of the reasons why range hood is not used. Energy use by the range hood is not a common concern among users.

The most common bathroom exhaust fan control is by a manual on/off switch. Automatic controls, such as by a timer, humidity sensor, and/or occupancy sensor, are becoming more common in homes built since 2011. Ordinal logistic regression results suggest that an increase number of bath fans is statistically associated with a decrease in the frequency of discomfort due to musty odor. An increase in number of occupants is associated with an increase in frequency of musty odor in homes.

Window opening frequency varies by season. In fall and spring, the majority of homes (70%) open their windows for at least 2–8 hours per day. In summer and winter, about 40% of open their windows for at least 2–8 hours per day. In spring, summer, and fall, ordinal logistic regression results suggest that survey respondents who rated outdoor air quality positively

tend to open their window more often. In all four seasons, “not enough air movement” is a significant parameter associated with more frequent window opening.

A small percentage (13%) of survey respondents reported that they use a stand-alone (portable) air filter, air purifier, or air cleaner in their homes. In households with at least one person diagnosed with asthma or allergies, the prevalence of air cleaner usage is about twice of that of households without. In addition, ordinal logistic regression results suggest that satisfaction with outdoor air quality is also a factor that has statistical significance on air cleaner usage. Survey respondents are more likely to use an air cleaner in their home if they give a lower rating on satisfaction with outdoor air quality. Satisfaction with indoor air quality is not a statistically significant factor associated with air cleaner usage.

Overall, analysis suggests that in this sample of largely pre-2008 homes, some of the mechanical ventilation systems (e.g., bathroom exhaust fan, fresh air vent) had a positive association with occupant satisfaction of indoor air quality and comfort. Homes with ventilation systems described as providing fresh air are correlated with higher indoor air quality satisfaction. In addition, having a vented range hood was associated with an increase in range hood usage, which suggests that new code requirements for effective kitchen exhaust may lead to better ventilation practices amongst occupants. Occupants are aware that a kitchen range hood exhausting to the outside is more effective than one that recirculates.

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Appendix A-1

Survey Recruitment



2015 California New Home Survey

Dear Customer,

SoCalGas is helping the Lawrence Berkley National Laboratory to conduct a research study on new homes in Southern California. We are inviting customers who live in a house, townhouse or duplex built in 2002 or later to complete a survey about their home.

The survey asks questions about your home, appliances, indoor air quality and demographics. All responses are confidential. Results will be used to help determine how homes can provide adequate ventilation and good indoor air quality, while improving energy efficiency. The survey has two sections. If you complete both sections it will take about 15-20 minutes.

[Click this link to access the survey.](#)

Or copy and paste the URL below into your internet browser:

<https://hengh-survey.lbl.gov>

Customers who complete the survey and enter their contact information will be entered into a drawing for \$100. One winner will be announced each month starting June 1 through October 1, 2015.*

The survey will close on September 30, 2015, but we ask you to **please complete the survey by June 30th, 2015**. Customers who complete the survey by June 30th will be eligible for the July 1 drawing. If you complete the survey after June 30th, you will be entered into the drawing for the month you complete the survey.

Your data is very valuable to our understanding of new homes in Southern California. We thank you for your time and participation.

If you have questions about this research study, please contact:

Rengie Chan
Research Scientist, Indoor Environment Department
Lawrence Berkley National Laboratory
wrcan@lbl.gov (510) 486-6570



Sincerely,
SoCalGas Customer Research

*Click [here](#) to read the sweepstakes rules.

Appendix A-2

California New Homes Survey 2015

Welcome to the 2015 California New Homes Survey!

This survey is part of a research study on new homes in California. This research will help inform how new homes can provide adequate ventilation and good indoor air quality, while reducing air infiltration and energy use.

We invite your participation if you live in a single-family detached house, townhouse, or duplex, built in 2002 or later. The survey includes questions about your home, appliances, and indoor air quality.

This survey has two sections:

- A 5-minute survey about your home.
- Additional 15-minute survey on mechanical systems and appliances, household activities and demographics.

The first 3 questions are mandatory for determining eligibility. After that, you can skip questions that you do not want to answer.

At the end of each survey section, you can enter a chance to win \$100 by submitting your contact information. You can double your chance of winning by completing both survey sections. One winner will be announced at the beginning of each month starting June 1 through October 1, 2015*. You will be entered into the drawing for the month you complete the survey.

This research is being conducted by Lawrence Berkeley National Laboratory (LBNL) with funding from the California Energy Commission. Results will be used only for research on how to provide adequate ventilation and improve indoor air quality. In order to protect your privacy, the data will be encrypted and password protected.

If you have questions about the research study, please contact:

Max Sherman, Ph.D.
Principal Investigator, Residential Building Systems Group
Lawrence Berkeley National Laboratory
mhsherman@lbl.gov (510) 486 4022

* Click [here](#) to read the sweepstakes rules.

Electronic Consent

By selecting ☐ Continue Survey below, you indicate that:

- You have read information about the survey.
- You are at least 18 years of age.
- You voluntarily agree to participate.

If you do not wish to continue, you may close this page by clicking the button below. You may still enter your contact information below for the chance to win \$100.

or

(If Exit Survey is selected)

One winner will be announced at the beginning of each month starting June 1 through October 1, 2015. Please note that if you are among the lucky winners, we will contact you to get your name and full street address to send you the \$100 in the form of a check.

You may also decline by clicking the No button below.

..... Yes! Enter to win.

..... No, I'm not interested.

(If selected yes)

Please provide contact information for how you would like to be contacted:

Name:

Please provide either your email or telephone number, or both.

Email:

Phone:

A. Eligibility Questions

Please answer ALL three questions to determine eligibility to participate in this survey.

1. Do you live in a single-family detached house, a townhouse, or a duplex?

..... Single-family detached house

..... Townhouse

..... Duplex

..... Other (e.g., apartment, mobile home)

2. What year was your house built?

Year Built:

3. What is the first three digits of your zip code?

Zip Code:

(If the dwelling is not eligible, the following message will be displayed and the survey will exit.)

Thank you for your interests in this study. Your home is not part of our targeted survey group.

If you would like to find out more about our work on ventilation and indoor air quality in homes, please visit our website at: <http://hengh.lbl.gov/>

(Survey will continue if the dwelling is eligible)

Yes! You live in a home that is eligible to participate in this survey.
Please answer to the best of your knowledge. You can skip any questions that you do not want answer.

B. Home and Household Characteristics

4. What is the size (floor area) of your home?
Square Feet:
5. How many people currently live in your home?
Number of People:
6. Do you have any of the following natural gas (NOT propane or LPG) appliances? Select all that apply.
 - Central gas furnace for heating
 - Gas wall furnace for heating
 - Freestanding gas heater
 - Gas water heater
 - Gas cooktop
 - Gas oven
 - Gas clothes dryer
 - Gas fireplace/ log set
 - Other. Please describe:
 - None
 - Don't know

LPG = Liquefied petroleum gas

7. Do you have any of the following mechanical ventilation equipment (see **Illustration 1**)?
Select all that apply.
 - Kitchen range hood or over the range microwave with exhaust fan
 - Kitchen exhaust fan separate from range hood
 - Bathroom exhaust fan

- Continuously operating ventilation exhaust fan
- Fresh air vent connected to heating and cooling system
- HRV (Heat Recovery Ventilator) or ERV (Energy Recovery Ventilator)
- Whole house fan
- Radon control system
- Other. Please describe:
- None
- Don't know

C. Air Quality In and Around Your Home

8. To what extent are you satisfied or dissatisfied with the indoor air quality in your home?

Very Dissatisfied	Neutral						Very Satisfied
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9. How would you rate the outdoor air quality near where you live?

Very Poor	Neutral						Excellent
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. How would you rate your home in protecting you from outdoor air pollution?

Very Ineffective	Neutral						Very Effective
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

D. Comfort Level in Your Home

11. In winter, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times in a month	Few times a week	Every day
Too hot in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Too cold in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

12. In summer, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times a month	Few times a week	Every day
Too hot in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Too cold in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

13. How often do the following conditions affect the comfort of occupants in your home?

	Never	Few times a year	Few times a month	Few times a week	Every day
Too much air movement.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Not enough air movement.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Indoor air is too dry.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Indoor air is too damp.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Indoor air has musty odor.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

E. Submit Your Response

Thank you for filling out this survey!

Your data is very valuable to our understanding of indoor air quality and mechanical ventilation in new California homes. Please select one of the following.

- Submit my responses
- Exit survey and do not use my responses

(If selected to exit without submitting responses)

The survey has ended. Your responses will not be used in this research.

If you have any questions about the survey, please contact:

Max Sherman, Ph.D.
Principal Investigator, Residential Building Systems Group
Lawrence Berkeley National Laboratory
mhsherman@lbl.gov (510) 486 4022

For more information about the results of this survey or the follow-up sampling study, please visit our website: <http://hengh.lbl.gov/>

(if selected to submit response)

To thank you for your help, please enter your contact information below to enter the chance to win \$100.

One winner will be announced at the beginning of each month starting June 1 through October 1, 2015. Please note that if you are among the lucky winners, we will contact you to get your name and full street address to send you the \$100 in the form of a check.

You may also decline by clicking the No button below.

..... Yes! Enter to win.

..... No, I'm not interested.

(If selected yes)

Please provide contact information for how you would like to be contacted:

Name:

Please provide either your email or telephone number, or both.

Email:

Phone:

F. Follow Up Study

(If the dwelling is a single-family detached house, was built in 2011 and after, and did not select "none" for natural gas appliance or mechanical ventilation equipment, the following recruitment information will appear.)

Your house may qualify for a follow-up study of indoor air quality and ventilation being conducted by Lawrence Berkeley National Laboratory (LBNL).

The study involves research teams visiting homes to measure the performance of ventilation equipment, and to set up air quality and ventilation monitoring devices that will remain in place for a one-week period.

Participants will receive up to \$230 when completing the study. Homes from the eligible list will be selected based on geographic location, and home and household characteristics. The field study will begin in November 2015 and continue throughout 2016.

If you are interested to receive more information about the study, please enter your contact information below. A member of our research team will contact you to ask you more questions about your home to determine eligibility within 4 weeks.

For more information about the sampling study, please visit our website: <http://hengh.lbl.gov/>

Would you like to find out more about our follow-up study?

..... Yes! I want to find out more

..... Yes! I want to find out more. Contact me at email/telephone already provided for a chance to win \$100.

..... No, I'm not interested.

(If selected yes to find out more about field study)

Please provide contact information for how you would like to be contacted:

Name:

Please provide either your email or telephone number, or both.

Email:

Phone:

G. Additional Survey Questions

In addition, we appreciate if you would answer a few more questions about your mechanical systems and appliances, household activities and demographics.

The additional questions take about 15 minutes to complete. Answering these additional questions will greatly increase the scientific value of the survey data.

You can also double your chance to win \$100!

If you do not wish to continue, you may close this page by clicking the Exit button below.

or

(If exit survey)

Survey has ended.

Thank you for filling out this survey! Your data is very valuable to our understanding of indoor air quality and mechanical ventilation in new California homes.

If you have any questions about the survey, please contact:

Max Sherman, Ph.D.
Principal Investigator, Residential Building Systems Group
Lawrence Berkeley National Laboratory
mhsherman@lbl.gov (510) 486 4022

For more information about the results of this survey or the follow-up sampling study, please visit our website: <http://hengh.lbl.gov/>

(If continue survey)

H. Detail Home and Household Characteristics

Thank you for continuing with our survey!

Please answer to the best of your knowledge. You can skip any questions that you do not want to answer.

14. How many stories are at or above ground?

Number Stories:

Half story or split-level counts as 0.5.

15. What type of foundation do you have? Select all that apply.

..... Concrete slab

..... Crawlspace

..... Basement

..... Don't know

If your home is located above a garage, select the foundation of the garage.

16. How many bedrooms are in your home?

Number Bedrooms:

17. How many bathrooms are in your home?

Number Full Bathrooms:

Number Half Bathrooms:

Half bathroom has a toilet and sink, but NO bath or shower.

18. Does your home have an attached garage?

Yes / No

If your home is located above a garage, select "Yes".

19. What year did you move into this home?

Year Moved In:

20. Do you own or rent your home?

..... Own (If yes → 21, skip otherwise)

..... Rent

..... Other

21. Are you the first owner of the property?

Yes / No

I. Natural Gas Appliances for Space Heating

You indicated that your home has the following natural gas appliances.

(Show answers from 6)

22. The next few questions ask about the type and location of gas appliances if present. Do you want to change your answers before going forward?

..... Yes, change my answers. (If yes → 23)

..... No change.

23. Do you have the following natural gas appliances? Select all that apply.

..... Central gas furnace for heating (If yes → 24)

..... Gas wall furnace for heating

..... Freestanding gas heater

..... Gas water heater (If yes → 28)

..... Gas cooktop

..... Gas oven

..... Gas clothes dryer (If yes → 29)

..... Gas fireplace/ log set

..... Other. Please describe:

..... None

..... Don't know

24. You indicated that you have a central natural gas furnace for heating.

Where is your furnace located?

..... Attic

..... Basement or crawlspace under the living space

..... Attached garage

..... Interior closet

..... Other space inside the home. Please describe:

..... Other space outside the home (e.g., furnace located in detached garage). Please describe:

..... Don't know

25. You indicated that you do NOT use natural gas for heating.

Which of the following heating appliances are used in your home? Select all that apply.

..... Central electric heating or heat-pump

..... Baseboard electric wall heater

- Freestanding electric heater
- Wood fireplace
- Wood or pellet stove
- Freestanding propane heater
- Freestanding kerosene heater
- No, I use natural gas for heating my home
- Other. Please describe:
- Don't know

(If central gas furnace or central electric heating or heat-pump → 26)

26. You indicated that you have a central forced air heating system.

Does your central forced air heating system have a particle air filter (**Illustration 2**)?

- Yes
- No, system does NOT have a particle air filter
- No, my home does NOT have a central forced air heating system
- Don't know

(If 26 is yes → 27)

27. What kind of particle air filter does your central forced air heating system have (see **Illustration 2**)?

- Traditional inexpensive filter
- Medium efficiency filter
- High efficiency filter
- Electrostatic filter
- Other. Please describe:
- Don't know

J. Other Natural Gas Appliances

28. You indicated that you have a natural gas water heater.

Where is your water heater located?

- Attic
- Basement or crawlspace under the living space
- Attached garage
- Interior closet
- Other space inside the home. Please describe:
- Other space outside the home (e.g., water heater located in detached garage). Please describe:
- Don't know

29. You indicated that you have a natural gas clothes dryer.

Where is your clothes dryer located?

- Laundry room
- Basement or crawlspace under the living space

- Attached garage
- Interior closet
- Other space inside the home. Please describe:
- Other space outside the home (e.g., clothes dryer located in detached garage).
Please describe:
- Don't know

K. Mechanical Ventilation Systems

You indicated that your home has the following mechanical ventilation equipment. (*Show answers from 7*)

30. The next few questions ask about your mechanical ventilation equipment (see **Illustration 1**) if present. Do you want to change your answers before going forward?

- Yes, change my answers. (If yes → 31)
- No change.

31. Do you have the following mechanical ventilation equipment (see **Illustration 1**)? Select all that apply.

- Kitchen range hood or over the range microwave with exhaust fan
(If yes → 32, 33)
- Kitchen exhaust fan separate from range hood (If yes → 33)
- Bathroom exhaust fan (If yes → 35)
- Continuously operating ventilation exhaust fan
- Fresh air vent connected to heating and cooling system (If yes → 38)
- HRV (Heat Recovery Ventilator) or ERV (Energy Recovery Ventilator)
(If yes → 38)
- Whole house fan
- Radon control system
- Other. Please describe:
- None
- Don't know

L. Kitchen Range Hood and/or Exhaust Fan

32. What type of kitchen range hood or over the range microwave do you have?

- Kitchen range hood exhausts air to outside
- Kitchen range hood blows air back into kitchen
- Over-the-range microwave exhausts air to outside
- Over-the-range microwave blows air back into kitchen
- Don't know

33. How often is the kitchen range hood or kitchen exhaust fan used when cooking with a cooktop?

- Always (5 out of 5 times)
- Most of the Time (4 out of 5 times)
- Sometimes (2 to 3 out of 5 times)
- Rarely (1 out of 5 times)
- Never (0 out of 5 times)
- Don't know

(If range hood used sometimes or less frequently → 34)

34. If the kitchen range hood or kitchen exhaust fan is NOT always used, what are the reasons for not using it? Select all that apply.

- Forget to turn it on
- Not needed for what is being cooked
- Too noisy
- Doesn't seem to remove cooking fumes or odors
- Open window instead
- Uses too much energy
- Other. Please describe:

M. Bathroom Exhaust Fan

35. What type(s) of bathroom exhaust fan control do you have?
Enter number of full and half bathroom(s) with the control types.

Types of Exhaust Fan Control	Number of Full Bathrooms	Number of Half Bathrooms
Auto-on timer control
Auto-on humidity sensor
Auto-on occupancy sensor
Comes on when light is turned on
Manual on/off switch
On all the time
No exhaust fan

Half bathroom has a toilet and sink, but NO bath or shower.

N. Particle Filtration in Mechanical Ventilation System

(If fresh air vent or HRV or ERV → 36)

36.) You indicated that you have a mechanical ventilation system that brings in outdoor air. Does the system have a particle air filter (see **Illustration 2**) that is separate from the central forced air system?
- Yes
 - No, outdoor air system does NOT have a separate particle air filter
 - No, mechanical ventilation system does NOT bring in outdoor air
 - Don't know

Examples of mechanical ventilation systems that bring in outdoor air include HRV (heat recovery ventilator), ERV (energy recovery ventilator), and fresh air vent connected to heating and cooling system.

(If 36 is yes → 37)

37.) What kind of particle air filter does your mechanical ventilation system that brings in outside air have (see **Illustration 2**)?
- Traditional inexpensive filter
 - Medium efficiency filter
 - High efficiency filter
 - Electrostatic filter
 - Other. Please describe:
 - Don't know

O. Mechanical Ventilation System Operation

(If 21 is yes, i.e. first owner of the property → 38)

38. Was the operation of the mechanical ventilation system explained to you when you bought or moved into the home?
- Yes
 - No
 - Don't know
39. Do you feel you understand how to operate your mechanical ventilation system properly?
- Yes
 - No
 - Not Sure

40. To what extent are you satisfied or dissatisfied with your mechanical ventilation system?

Very Dissatisfied			Neutral			Very Satisfied		
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

(If not very satisfied → 41)

41. If you are NOT very satisfied with your mechanical ventilation system, what are the reason(s) for dissatisfaction? Select all that apply.

- Too noisy
- Too drafty
- Difficult to operate
- Difficult to maintain
- Uses too much energy
- Brings in dust, odor, or air pollutants from outdoor
- Not effective
- Other. Please describe:

P. Occupancy and Indoor Activities

The next few questions ask about indoor activities, such as cooking, that can affect the indoor air quality in your home.

42. On average, how many hours per day is your home occupied by at least one person, including day and night hours?

	Fewer than 8 hours per day	8 to 12 hours per day	12 to 16 hours per day	16 to 20 hours per day	More than 20 hours per day
Weekday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Weekend	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

43. On average, how many times per week is your cooktop and/or oven used for cooking, including boiling water?

	0 time per week	1 to 2 times per week	3 to 4 times per week	5 to 6 times per week	7 times per week
Breakfast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lunch	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dinner	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	0 time per week	1 to 2 times per week	3 to 4 times per week	5 to 6 times per week	7 times per week
Other cooking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

44. On average, how many times per week do the following activities occur inside your home?
Enter "0" if occurrence is less frequent than once a week.

Use shower (Times per week)

Use bath or indoor Jacuzzi (Times per week)

Use dishwasher (Times per week)

Use washing machine (Loads per week)

Hang clothes to dry indoors (Loads per week)

Q. Window Opening

45. On average, how many hours per day are your windows open?

	0 hour per day	1 to 2 hour per day	2 to 8 hours per day	8 to 16 hours per day	More than 16 hours per day
Summer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fall	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Winter	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Spring	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

R. Indoor Activities

46. On average, how often do the following activities occur inside your home?

	Never	Few times a year	Few times a month	Few times a week	Every day
Smoking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Burn candle or incense	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vacuuming	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use cleaning agent for floor cleaning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Never	Few times a year	Few times a month	Few times a week	Every day
Use spray air freshener	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use pesticide spray	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use paints, glue, solvents (e.g., hobbies, home repairs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use humidifier	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Use dehumidifier	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

S. Other Indoor Sources

47. Are plug-in or stick air fresheners, or other scented decorations, used in your home?

- Yes
- No
- Don't know

48. Do occupants wear shoes in your home?

- Yes
- No
- Don't know

49. How many dogs, cats, or other furry pets are in the home?

Number of Pets:

T. Use of Air Cleaners

50. Do you use a stand-alone (portable) air filter, air purifier, or air cleaner in the home?

- Yes
- No
- Don't know

(If 50 is yes →51)

51. Where is your stand-alone (portable) air filter, air purifier, or air cleaner located in your home? Select all that apply.

- Master bedroom
- Other bedroom(s)
- Living room
- Home office
- Other. Please describe:

52. Has anyone in the household been diagnosed with asthma?

- Yes
- No
- Don't know

53. Has anyone in the household been diagnosed with allergies?

- Yes
- No
- Don't know

U. Demographic Information

The next questions will help us interpret the results of the survey. All responses will be kept confidential.

54. Please indicate the number of household member(s) in the following age categories.

	Number of household member(s)
0 to 17 Years Old
18 to 65 Years old
Over 65 Years old

55. What is the highest education level of head of household?

- No schooling completed
- 1 to 8th grade
- 9th to 12th grade
- Completed high school (high school diploma, GED credential)
- Some college
- Associate's degree
- College degree (Bachelor's degree)
- Graduate degree (Master's, Professional school, Doctorate degree)

56. Please indicate all races and/or ethnicities of people living in your household.

- American Indian, Alaska Native
- Asian or Pacific Islander
- Black, African American
- Hispanic/ Latino
- White, Caucasian
- Other, specify:
- Mixed race, specify:

57. What is the total income of all member(s) of your household combined?

- Less than \$35,000
- \$35,000 to \$ 49,999
- \$50,000 to \$ 74,999
- \$75,000 to \$ 99,999
- \$100,000 to \$150,000
- Greater than \$150,000

V. Submit Your Response

You have reached the end of the survey. Thank you for taking the time to help us with this important research!

Your data is very valuable to our understanding of indoor air quality and mechanical ventilation in new California homes.

Please select one of the following.

- Submit my responses
- Exit survey and do not use my responses

(If selected to exit without submitting responses)

The survey has ended. Your responses will not be used in this research.

If you have any questions about the survey, please contact:

Max Sherman, Ph.D.
Principal Investigator, Residential Building Systems Group
Lawrence Berkeley National Laboratory
mhsherman@lbl.gov (510) 486 4022

For more information about the results of this survey or the follow-up sampling study, please visit our website: <http://hengh.lbl.gov/>

(if selected to submit responses)

To thank you for your help, please enter your contact information below to enter the chance to win \$100.

One winner will be announced at the beginning of each month starting June 1 through October 1, 2015. Please note that if you are among the lucky winners, we will contact you to get your name and full street address to send you the \$100 in the form of a check.

You may also decline by clicking the No button below.

..... Yes! Enter to win.

..... Yes! Enter to win. I already entered my contact information.

..... No, I'm not interested.

(If selected yes)

Please provide contact information for how you would like to be contacted:

Name:

Please provide either your email or telephone number, or both.

Email:

Phone:

W. Follow Up Study

(If the dwelling is a single-family detached house, was built in 2011 and after, and did not select "none" for natural gas appliance or mechanical ventilation equipment, the following recruitment information will appear.)

Your house may qualify for a follow-up study of indoor air quality and ventilation being conducted by Lawrence Berkeley National Laboratory (LBNL).

The study involves research teams visiting homes to measure the performance of ventilation equipment, and to set up air quality and ventilation monitoring devices that will remain in place for a one-week period.

Participants will receive up to \$230 when completing the study. Homes from the eligible list will be selected based on geographic location, and home and household characteristics. The field study will begin in November 2015 and continue throughout 2016.

If you are interested to receive more information about the study, please enter your contact information below. A member of our research team will contact you to ask you more questions about your home to determine eligibility within 4 weeks.

For more information about the sampling study, please visit our website: <http://hengh.lbl.gov/>

Would you like to find out more about our follow-up study?

..... Yes! I want to find out more

..... Yes! I want to find out more. Contact me at email/telephone already provided for a chance to win \$100.

..... No, I'm not interested.

(If selected yes to find out more about field study)

Please provide contact information for how you would like to be contacted:

Name:

Please provide either your email or telephone number, or both.

Email:

Phone:

X. End of Survey

Thank you for filling out this survey! Your data is very valuable to our understanding of indoor air quality and mechanical ventilation in new California homes.

If you have any questions about the survey, please contact:

Max Sherman, Ph.D.

Principal Investigator, Residential Building Systems Group

Lawrence Berkeley National Laboratory

mhsherman@lbl.gov (510) 486 4022

For more information about the results of this survey or the follow-up sampling study, please visit our website: <http://hengh.lbl.gov/>

Illustration 1

Mechanical Ventilation Equipment	
<p>Kitchen range hood/ over-the-range microwave with exhaust fan</p> 	<p>Kitchen exhaust fan separate from range hood</p> 
<p>Bathroom exhaust fan</p> 	<p>Continuously operating ventilation exhaust fan</p> 
<p>Fresh air vent connected to heating and cooling system</p> 	<p>HRV (Heat Recovery Ventilator) or ERV (Energy Recovery Ventilator)</p> 
<p>Whole house fan</p> 	<p>Radon control system</p> 

Illustration 2

Types of Air Filters		Air Filter Efficiency Ratings		
		MERV	MPR	FPR
Traditional inexpensive filter		0-4	--	--
		5-7	300 600	4-5
Medium efficiency filter		8-11	1000 1200 1500	6-7 8-9
High efficiency filter		≥12	1900 2200	10
Electrostatic filter		--	--	--

MERV = Minimum efficiency reporting value

MPR = Microparticle performance rating

FPR = Filter performance rating

Appendix A-3

Table A3-1 Occupant satisfaction with indoor air quality (IAQ), outdoor air quality (OAQ), and other indoor environmental conditions.

Parameter	Survey Response									
	Counts (%)									
Overall IAQ satisfaction	-4 (Very Dissatisfied)	-3	-2	-1	Neutral	1	2	3	4 (Very Satisfied)	NA
	40 (1.4%)	33 (1.2%)	71 (2.6%)	124 (4.4%)	569 (20.5%)	224 (8%)	543 (20%)	572 (21%)	589 (21%)	6
Overall OAQ satisfaction	-4 (Very Dissatisfied)	-3	-2	-1	Neutral	1	2	3	4 (Very Satisfied)	
	121 (4.4%)	115 (4.2%)	201 (7.3%)	277 (10%)	503 (18%)	305 (11%)	548 (20%)	428 (15%)	268 (9.6%)	5
How often the following conditions affect the comfort?	Never	Few times a year	Few times in a month	Few times a week	Everyday	NA				
Winter (Too hot)	1331 (48%)	692 (25%)	277 (10%)	193 (7%)	95 (3%)	183 (7%)				

Parameter	Survey Response					
	Counts (%)					
Winter (Too cold)	750 (27%)	922 (33%)	446 (16%)	352 (13%)	192 (7%)	109 (4%)
Summer (Too hot)	367 (13%)	764 (28%)	477 (17%)	623 (23%)	505 (18%)	35 (1%)
Summer (Too cold)	1460 (53%)	546 (20%)	228 (8%)	153 (6%)	96 (3%)	288 (10%)
Too much air movement	2006 (72%)	388 (14%)	150 (6%)	89 (3%)	36 (1%)	102 (4%)
Not enough air movement	1033 (37%)	754 (27%)	420 (15%)	334 (12%)	162 (6%)	68 (3%)
Indoor air is too dry	1363 (49%)	654 (24%)	344 (12%)	187 (7%)	127 (5%)	96 (3%)
Indoor air is too damp	2135 (77%)	385 (13.8%)	81 (3%)	49 (2%)	5 (0.2%)	116 (4%)
Indoor air has musty odor	2048 (74%)	414 (14.9%)	126 (4.5%)	53 (1.9%)	19 (0.7%)	111 (4%)

Table A3-2 Kitchen range hood type and usage frequency (N = 2,516).

Parameter		Survey Response Counts (%)				
Type of range hood?	Kitchen range hood exhausts air to outside	Kitchen range hood blows air back into kitchen	Over-the-range microwave exhausts air to outside	Over-the-range microwave blows air back into kitchen	Don't know	NA
	1081 (43%)	107 (4%)	901 (33%)	222 (8%)	131 (5%)	74 (3%)
How often do you use range hood when cooking with cooktop?						
Always	150 (14%)	11 (10%)	118 (13%)	14 (6%)	10 (8%)	
Most of the Time	293 (27%)	19 (18%)	181 (20%)	38 (17%)	14 (11%)	
Sometimes	347 (32%)	26 (24%)	289 (32%)	57 (26%)	43 (33%)	
Rarely	266 (25%)	42 (39%)	286 (32%)	96 (43%)	56 (43%)	
Never	23 (2%)	9 (8%)	21 (2%)	17 (8%)	5 (4%)	
Don't Know	2 (<0.1%)	0 (0%)	5 (0.5%)	0 (0%)	3 (2%)	
NA			1			

Table A3-3 Reasons for not using the range hood
(N = responses that answered range hood is used sometimes or less frequently).

Parameter		Survey Response (%)				
Type of range hood	Kitchen range hood exhausts air to outside	Kitchen range hood blows air back into kitchen	Over-the-range microwave exhausts air to outside	Over-the-range microwave blows air back into kitchen	Don't know	NA
N	638	77	596	170	107	
What are the reasons for not using the kitchen range hood or exhaust fan?						
Forget	108 (17%)	8 (10%)	108 (18%)	30 (18%)	17 (16%)	17
Not Needed	537 (84%)	56 (73%)	488 (82%)	120 (71%)	86 (80%)	64
Too Noisy	179 (28%)	17 (22%)	175 (29%)	42 (25%)	31 (29%)	20
Doesn't Work	45 (7%)	22 (29%)	54 (9%)	45 (26%)	7 (7%)	4
Open Window	59 (9%)	10 (18%)	70 (12%)	36 (21%)	20 (19%)	12
Uses Too Much Energy	6 (1%)	1 (2%)	8 (1.3%)	2 (1%)	3 (3%)	0
Other						

Table A3-4 Survey responses on frequency of window opening by season.

Window Opening						
	0 hours per day	1–2 hours per day	2–8 hours per day	8–16 hours per day	More than 16 hours per day	NA
Summer	1194	303	390	439	334	111
	(43%)	(11%)	(14%)	(16%)	(12%)	(4%)
Fall	505	400	698	596	449	123
	(18%)	(14%)	(25%)	(22%)	(16%)	(4%)
Winter	1044	541	506	356	198	126
	(38%)	(20%)	(18%)	(13%)	(7%)	(5%)
Spring	437	388	699	609	510	128
	(16%)	(14%)	(25%)	(22%)	(18%)	(5%)

Table A3-5 Survey responses on air cleaner usage in household with and without diagnosed case(s) of asthma and/or allergy.

Use of Air Cleaner	Asthma (N=2,587)		Allergy (N=2,569)	
	Yes	No	Yes	No
Yes	115	255	258	111
	(23%)	(12%)	(18%)	(10%)
No	396	1821	1185	1015
	(77%)	(88%)	(82%)	(90%)